



UNIVERSITÉ DE  
SHERBROOKE



# Cartographie, Localisation et Planification Simultanées 'en Ligne', à Long Terme et à Grande Échelle pour Robot Mobile

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Soutenance de thèse de doctorat

Département de génie électrique et génie informatique, IntRoLab, 3IT

19 Décembre 2018

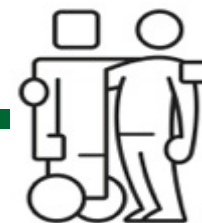




# Plan

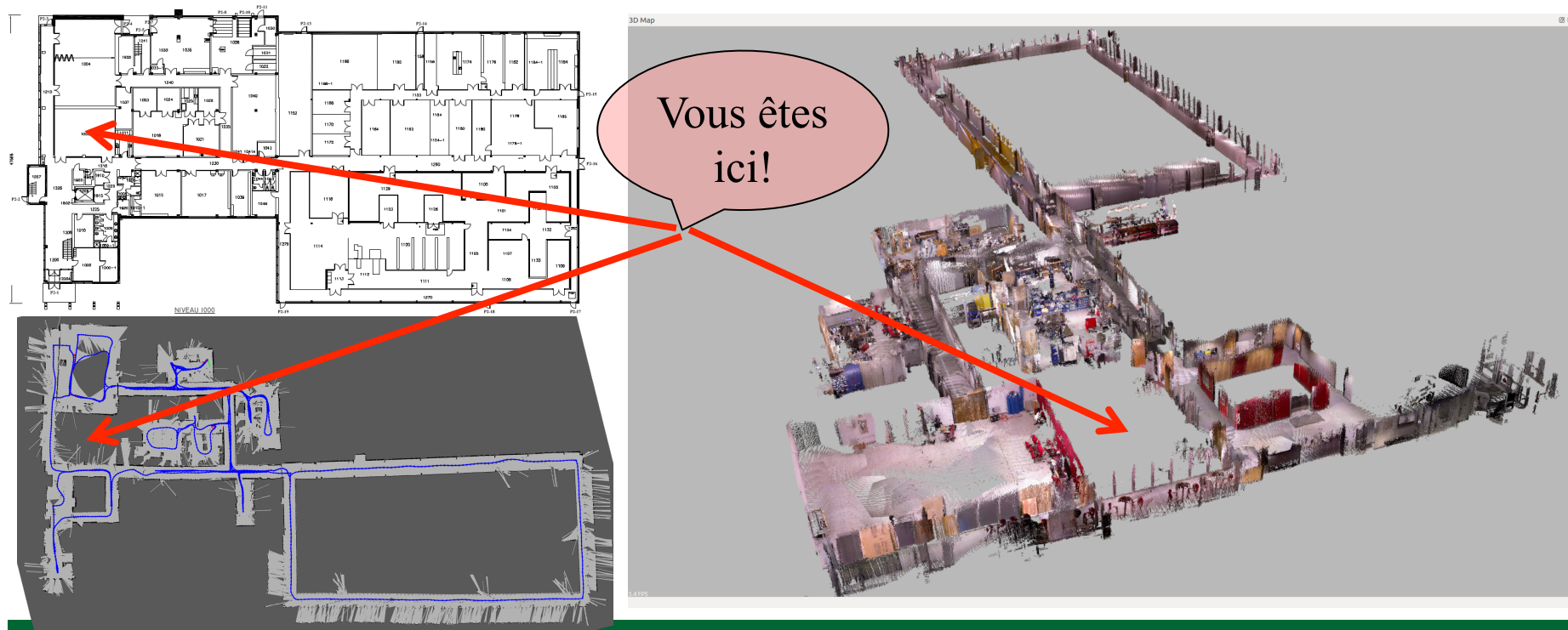
- Mise en contexte
- Énoncé du problème de cartographie 'en ligne', à long terme et à grande échelle
- Description de l'approche de gestion de mémoire et de planification
  - Résultats navigation autonome à long terme
- Schéma d'architecture
- Résultats comparatifs entre caméras et lasers
- Conclusion





# Cartographie et Localisation Simultanées

## *Simultaneous Localization And Mapping (SLAM)*





# Cartographie et Localisation Simultanées

## *Simultaneous Localization And Mapping (SLAM)*

- **Localisation précise externe non disponible**
  - Exemple: pas de GPS



# Cartographie et Localisation Simultanées

## *Simultaneous Localization And Mapping (SLAM)*

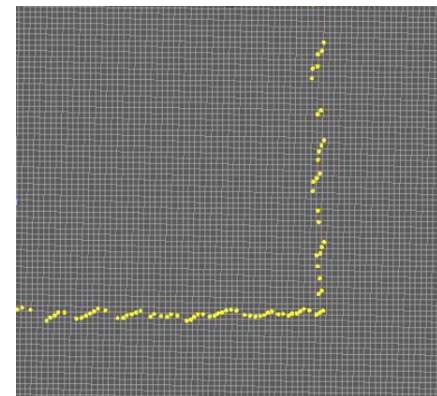
- Localisation précise externe non disponible
  - Exemple: pas de GPS
- **Carte de l'environnement non disponible**



# Cartographie et Localisation Simultanées

## *Simultaneous Localization And Mapping (SLAM)*

- Localisation précise externe non disponible
  - Exemple: pas de GPS
- Carte de l'environnement non disponible
- **Les capteurs ne sont pas parfaits**





# Cartographie et Localisation Simultanées

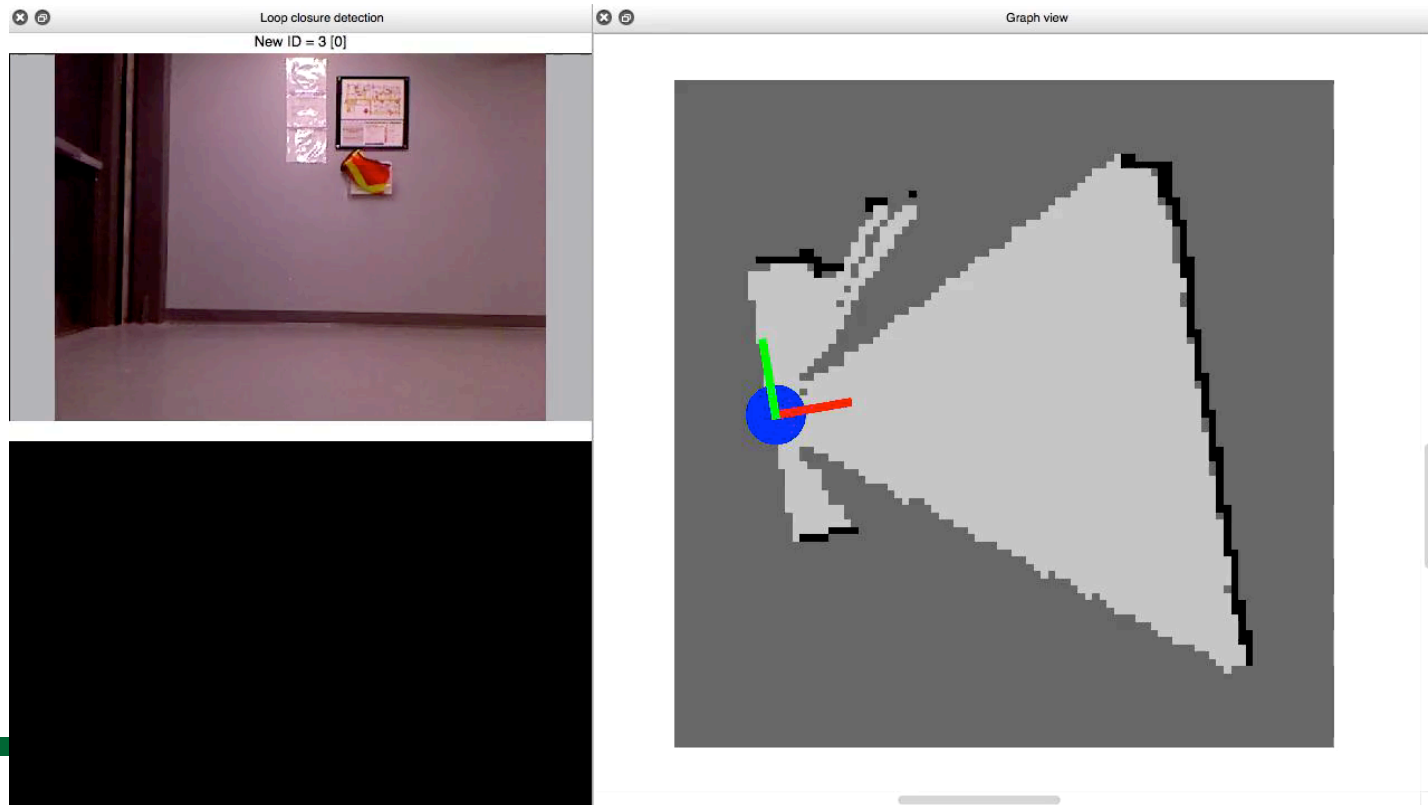
## *Simultaneous Localization And Mapping (SLAM)*

- Localisation précise externe non disponible
  - Exemple: pas de GPS
- Carte de l'environnement non disponible
- Les capteurs ne sont pas parfaits
- **Problème de “l’oeuf ou la poule?”**



# Cartographie et Localisation Simultanées

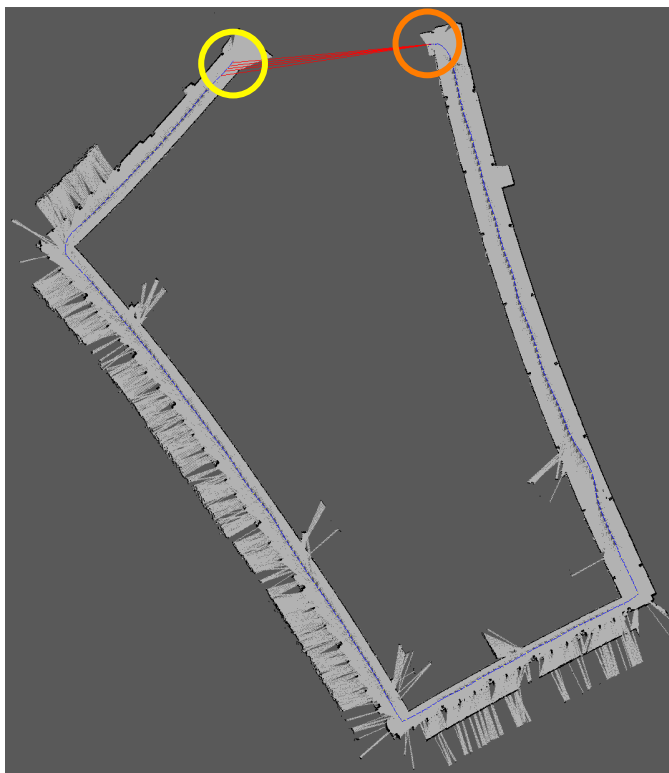
## *Simultaneous Localization And Mapping (SLAM)*





# Cartographie et Localisation Simultanées

*Simultaneous Localization And Mapping (SLAM)*



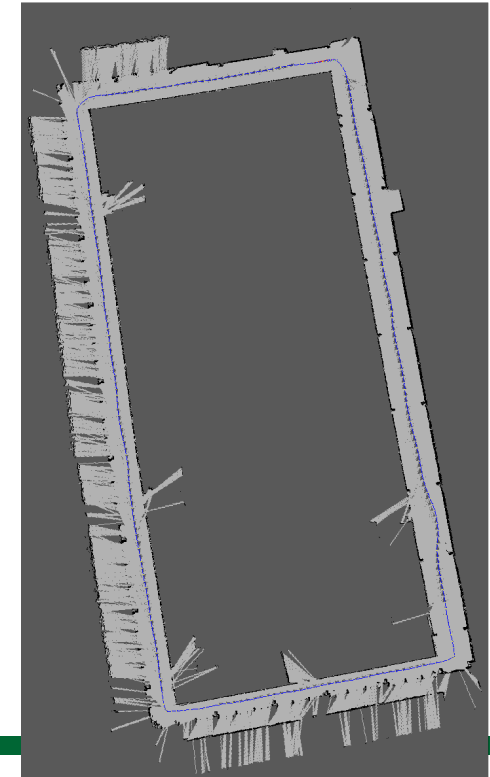
1) Détection de fermeture de boucle

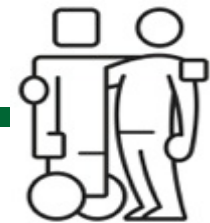


2) Optimisation du graphe

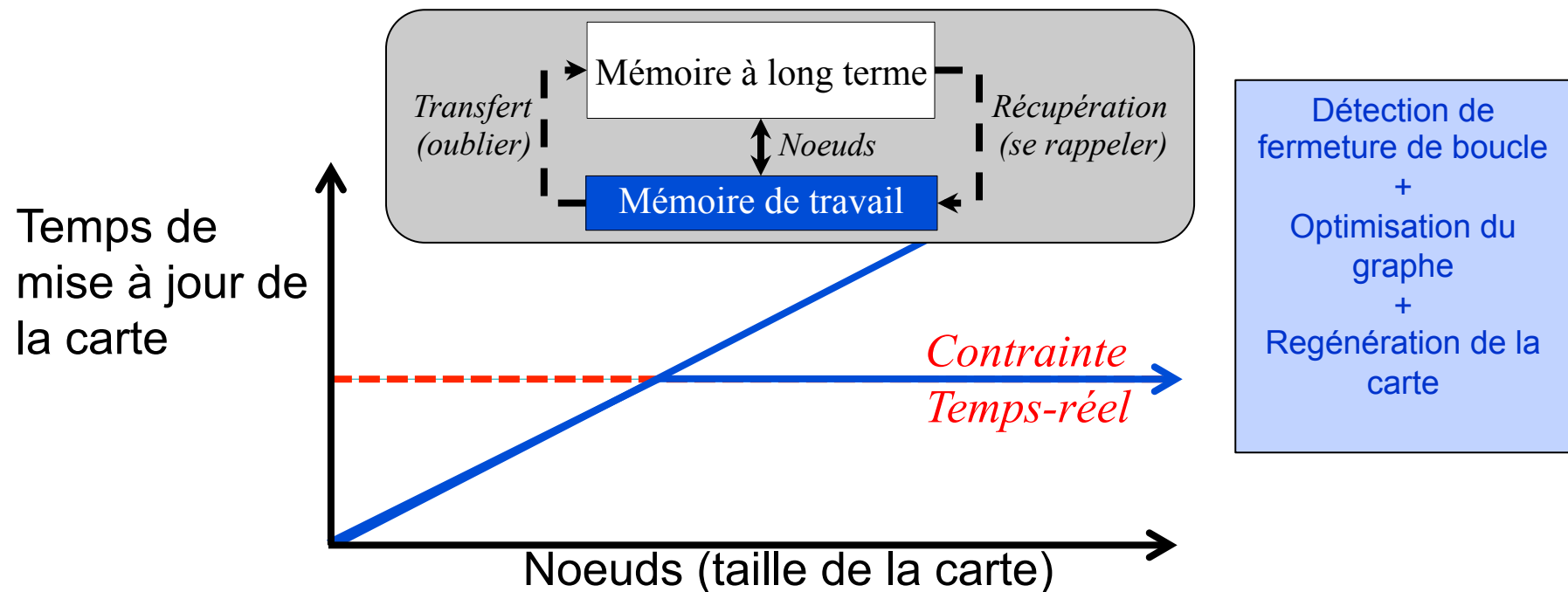


3) Régénération de la carte





## Problématique de mise à jour ‘en ligne’, à long terme et à grande échelle

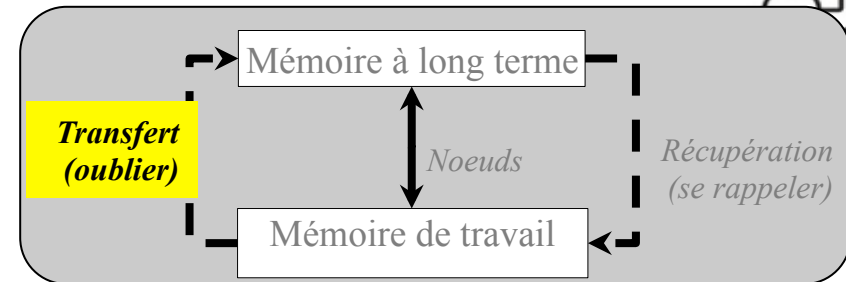




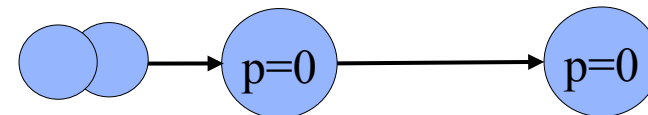
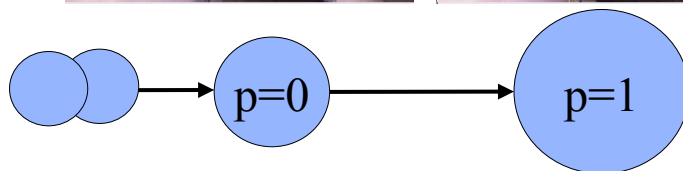


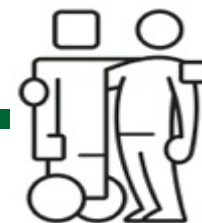
# Gestion de mémoire

Quels noeuds sont transférés en premier?

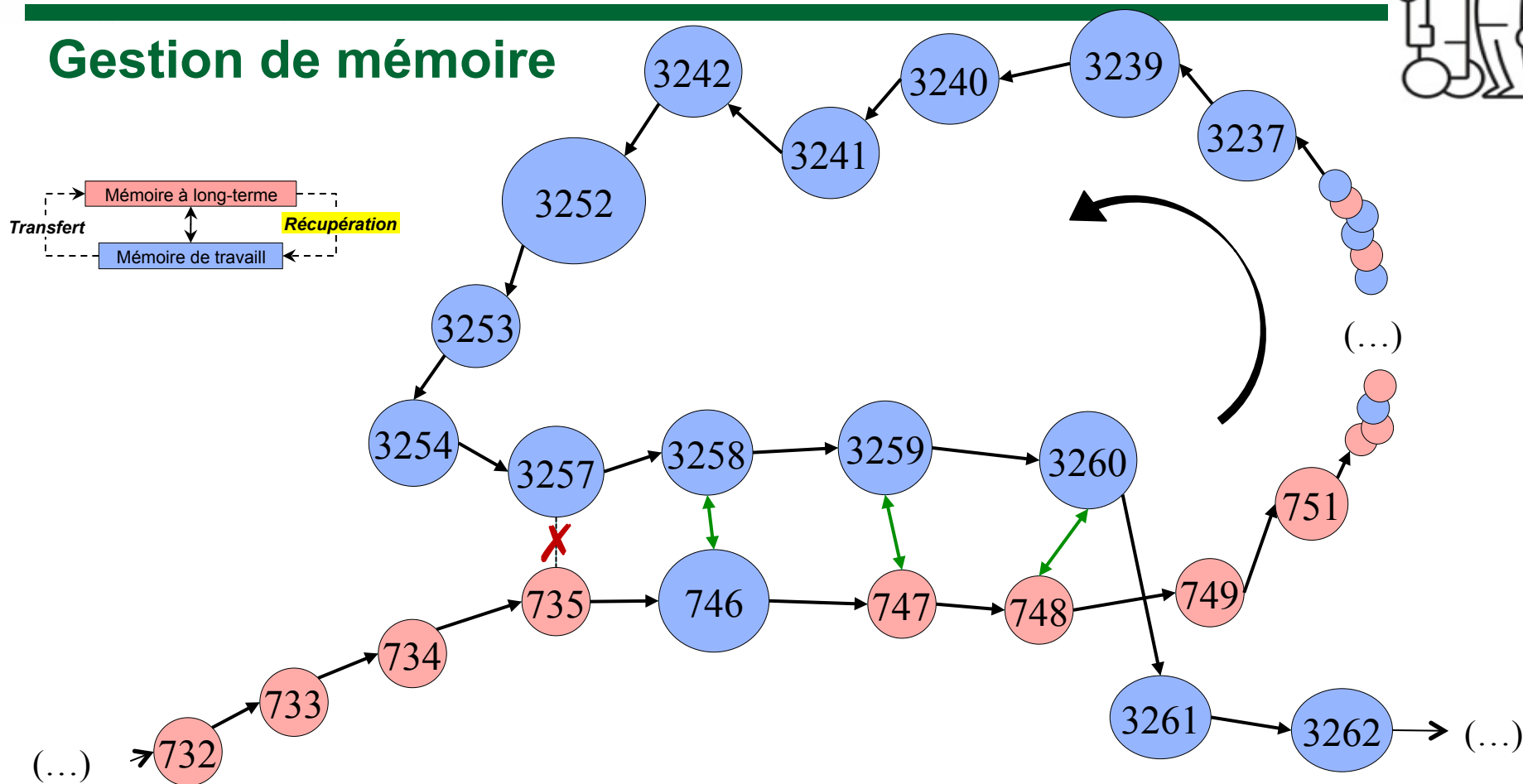


Noeuds vus moins souvent et plus vieux (poids moins élevé)



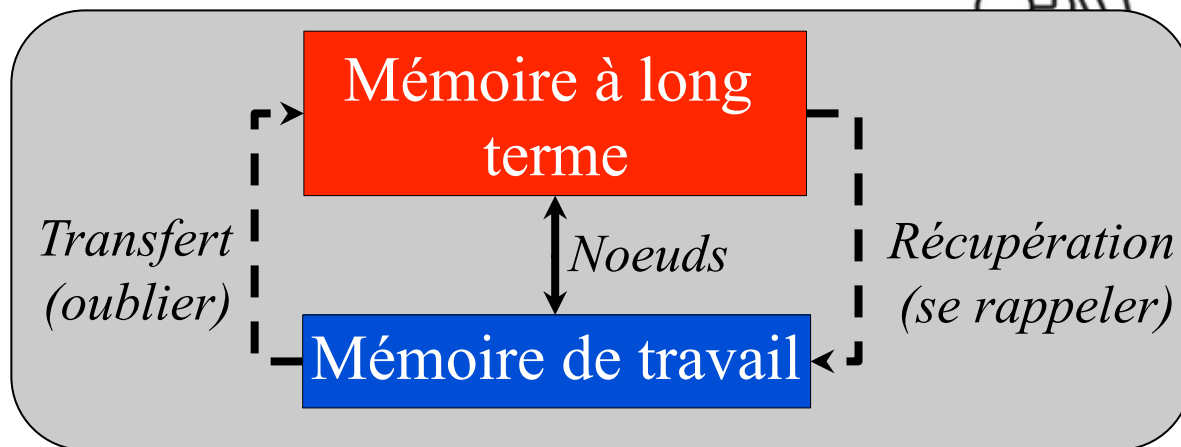
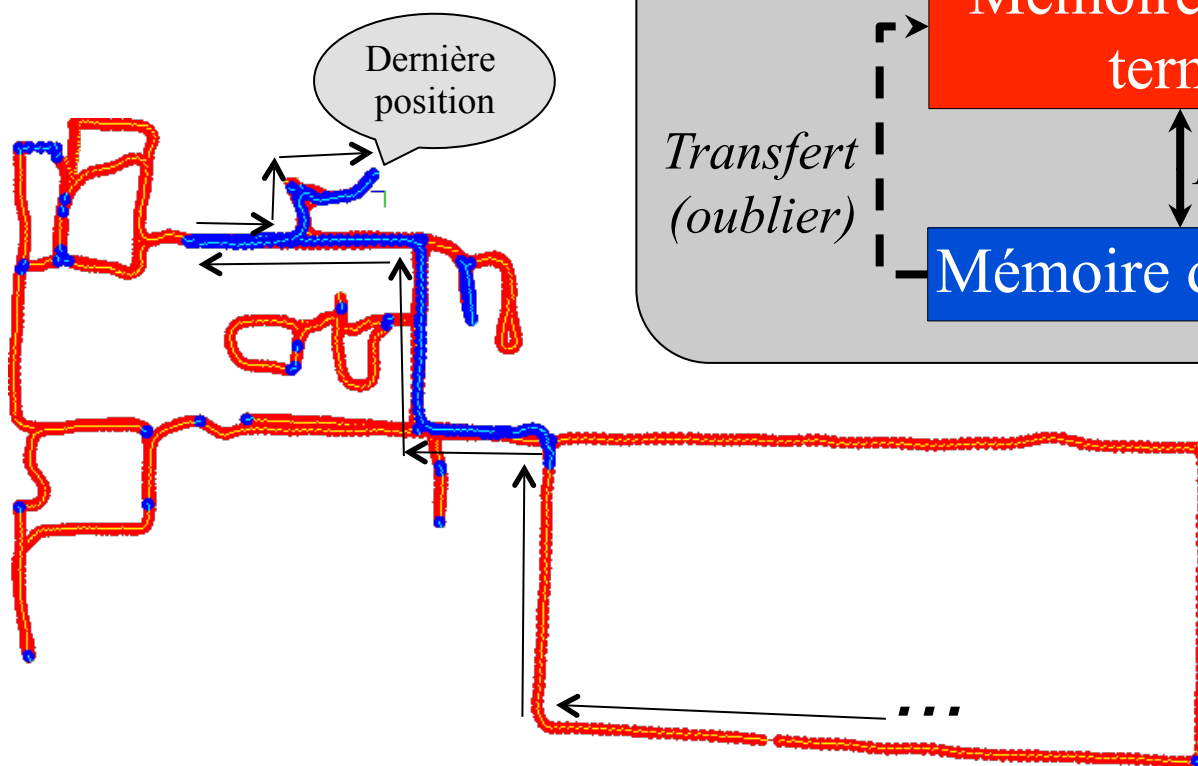


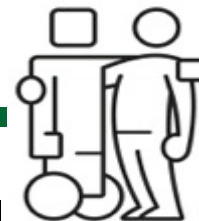
## Gestion de mémoire





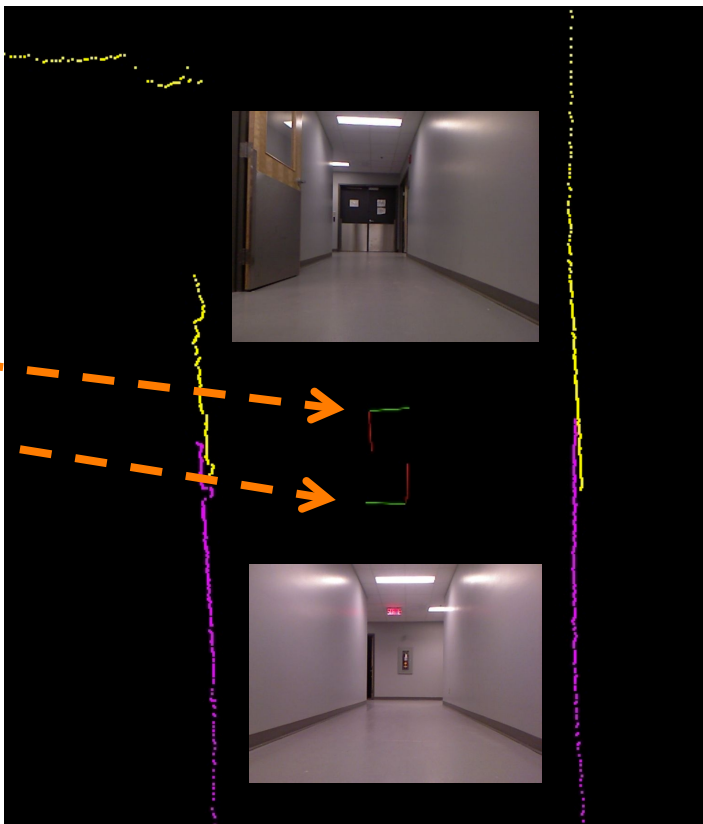
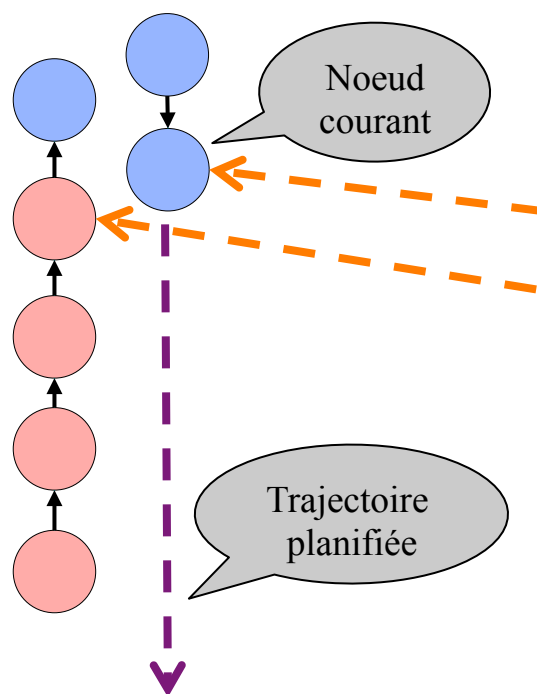
## Gestion de mémoire





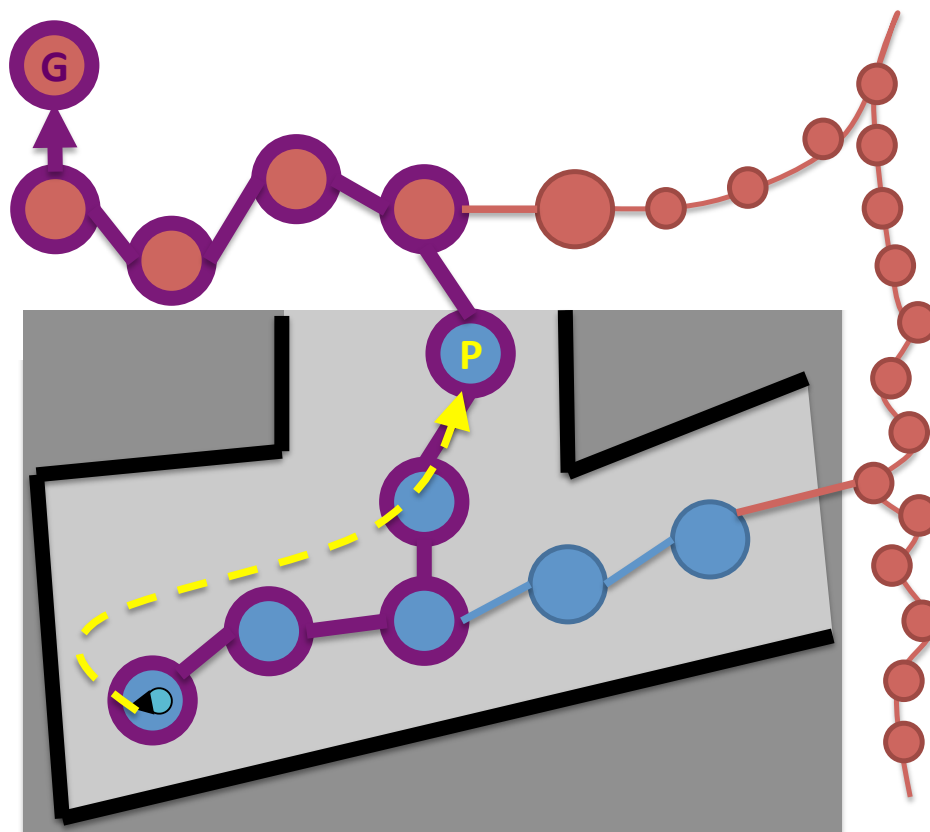
# Gestion de mémoire

## Suivi de trajectoire



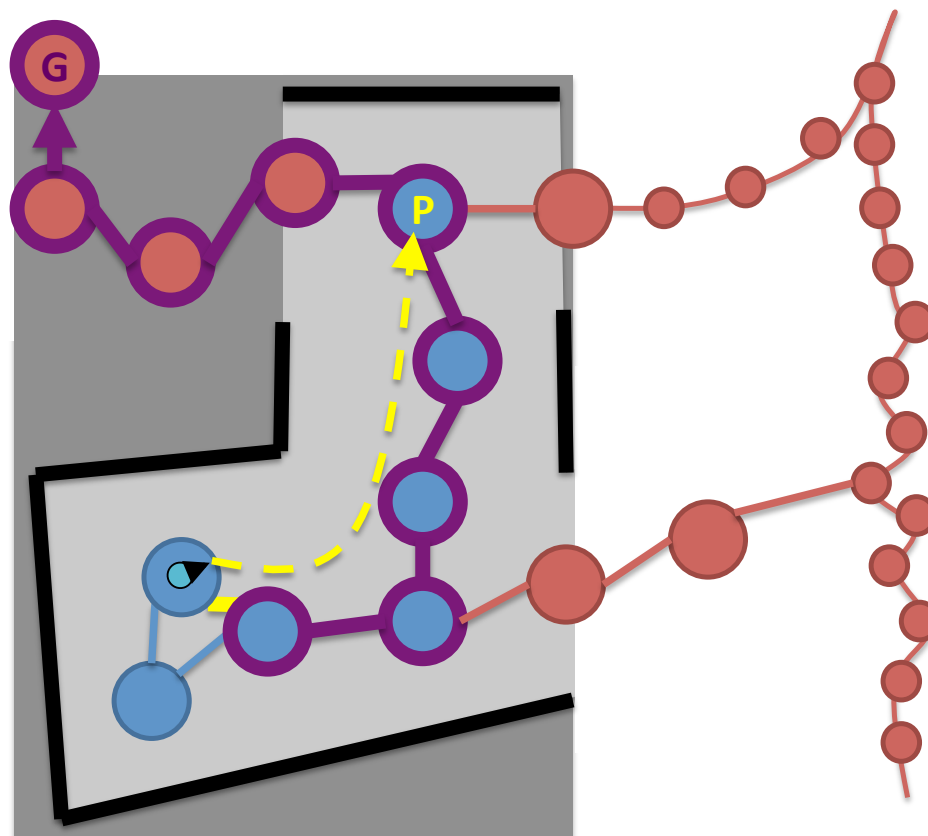


## Gestion de mémoire



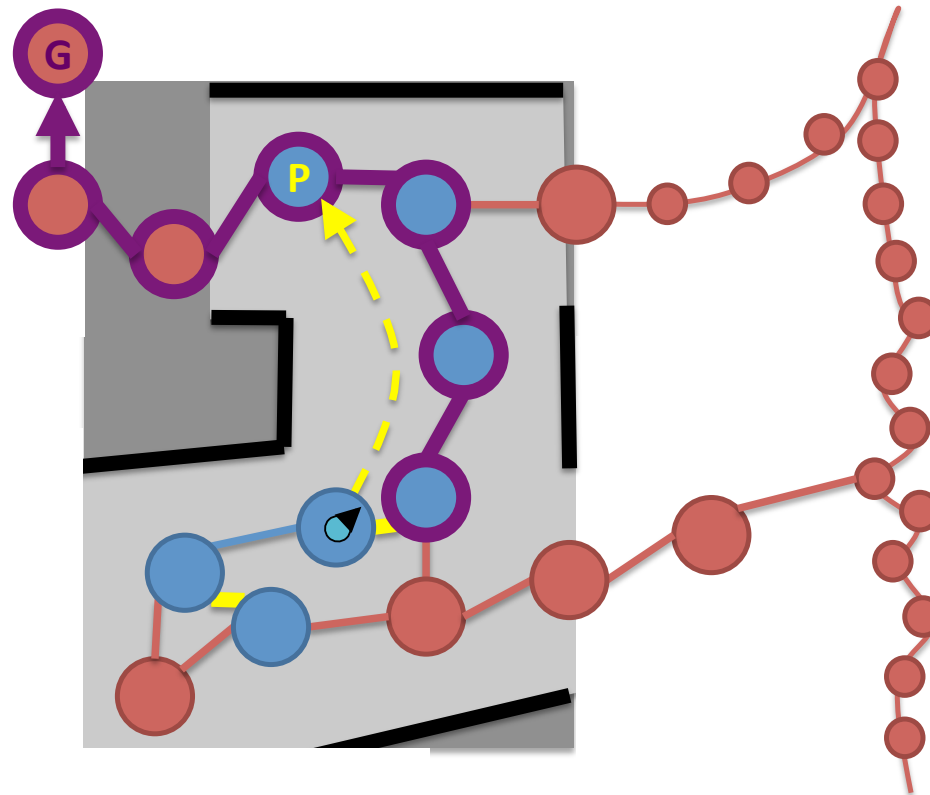


## Gestion de mémoire



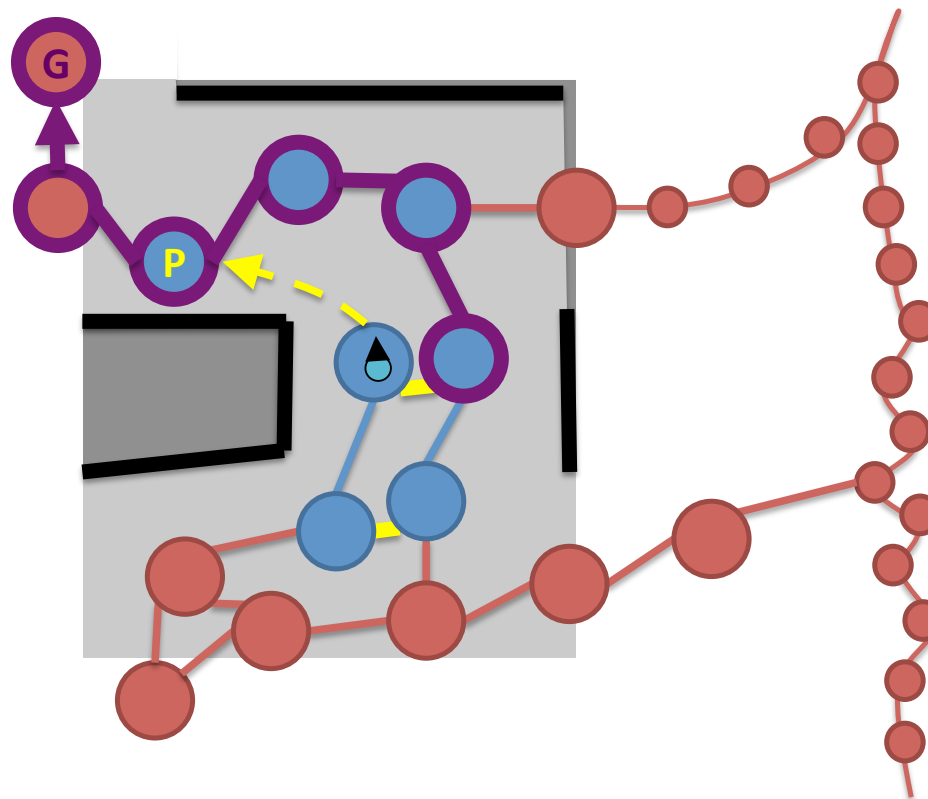


## Gestion de mémoire





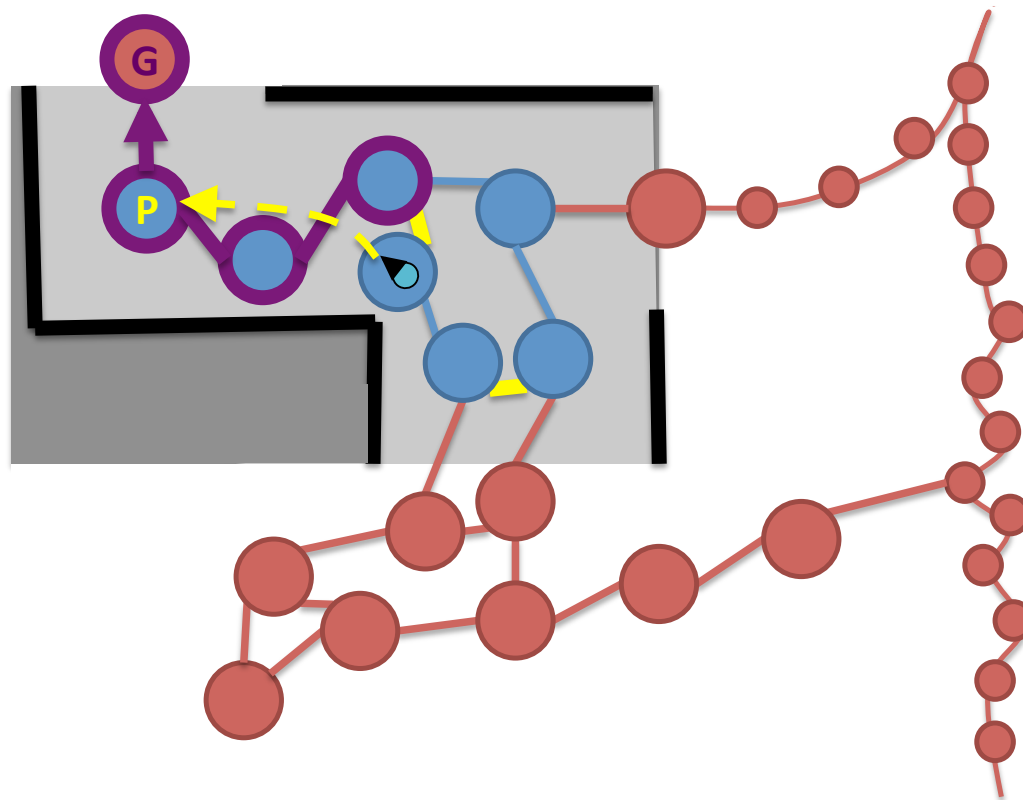
## Gestion de mémoire





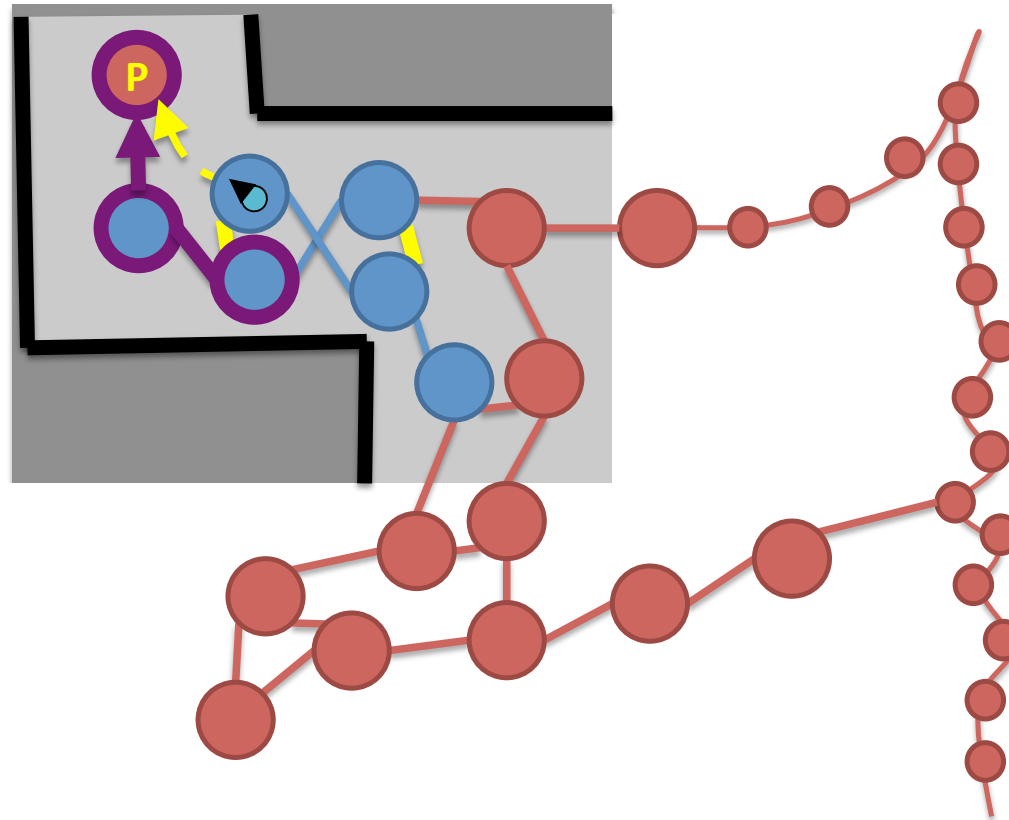


## Gestion de mémoire





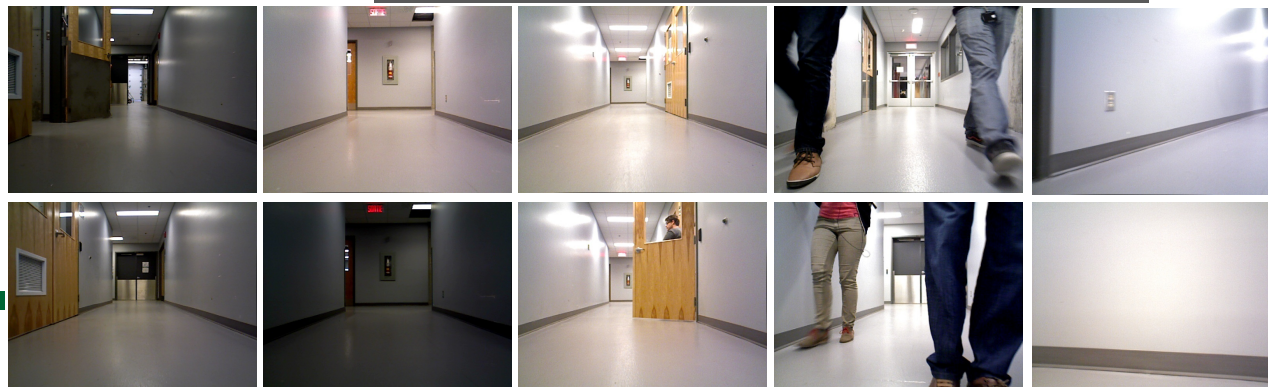
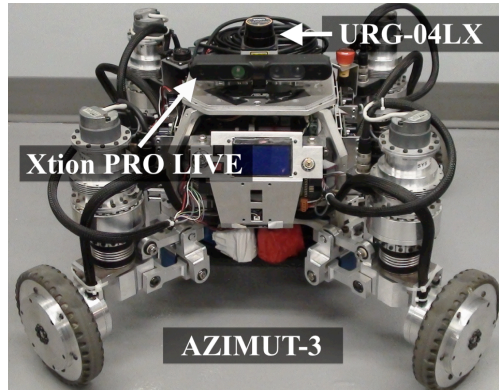
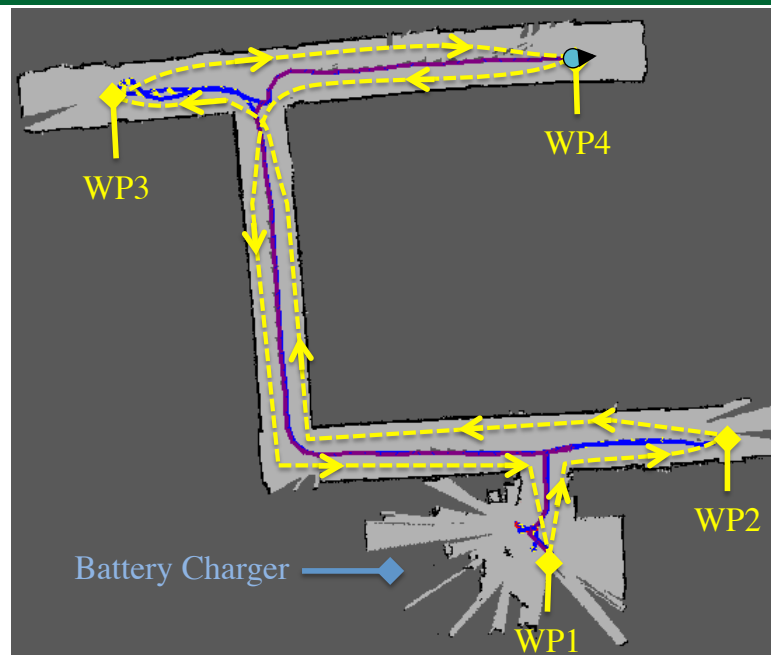
## Gestion de mémoire

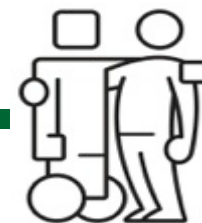


## Gestion de mémoire

### Expérience

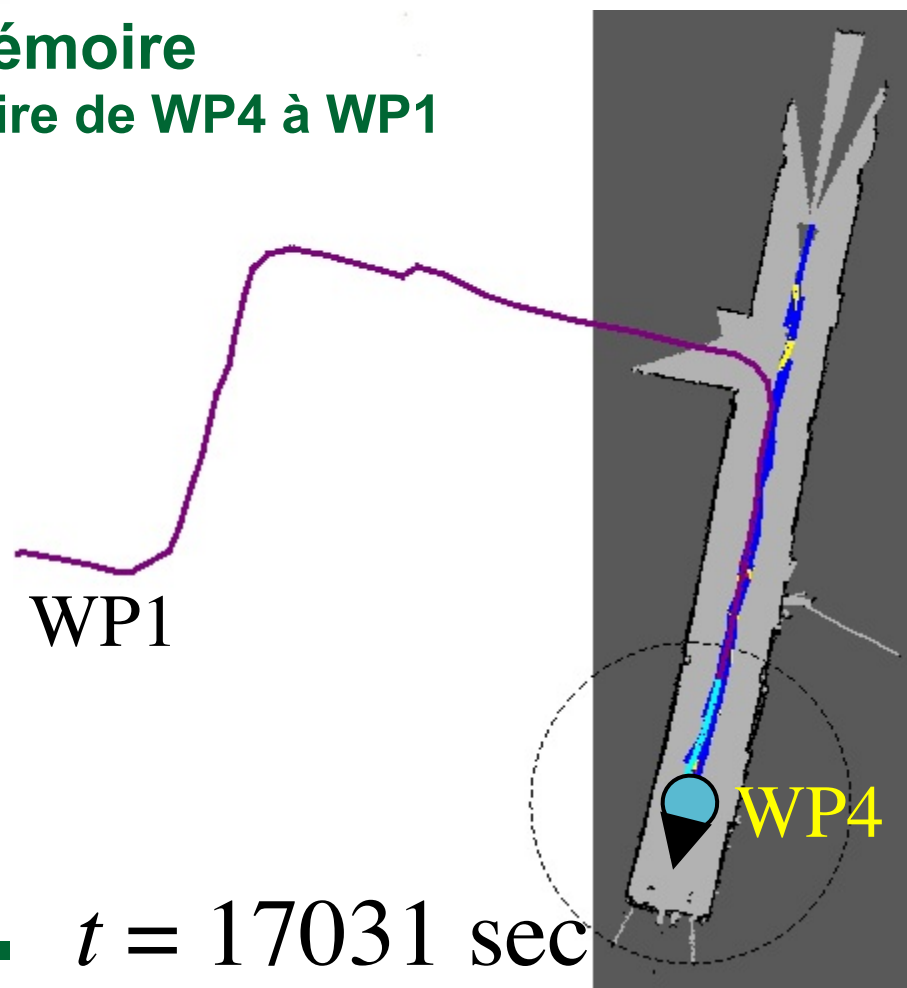
- Robot patrouilleur
  - Patrouiller entre 4 points de passage (WP1, WP2, WP3, WP4)
  - 11 sessions (~45 min chacune) sur 2 semaines (total ~8 heures)
  - 111 cycles
  - 10.5 km

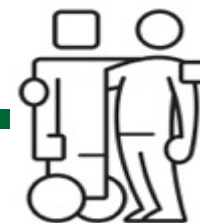




## Gestion de mémoire

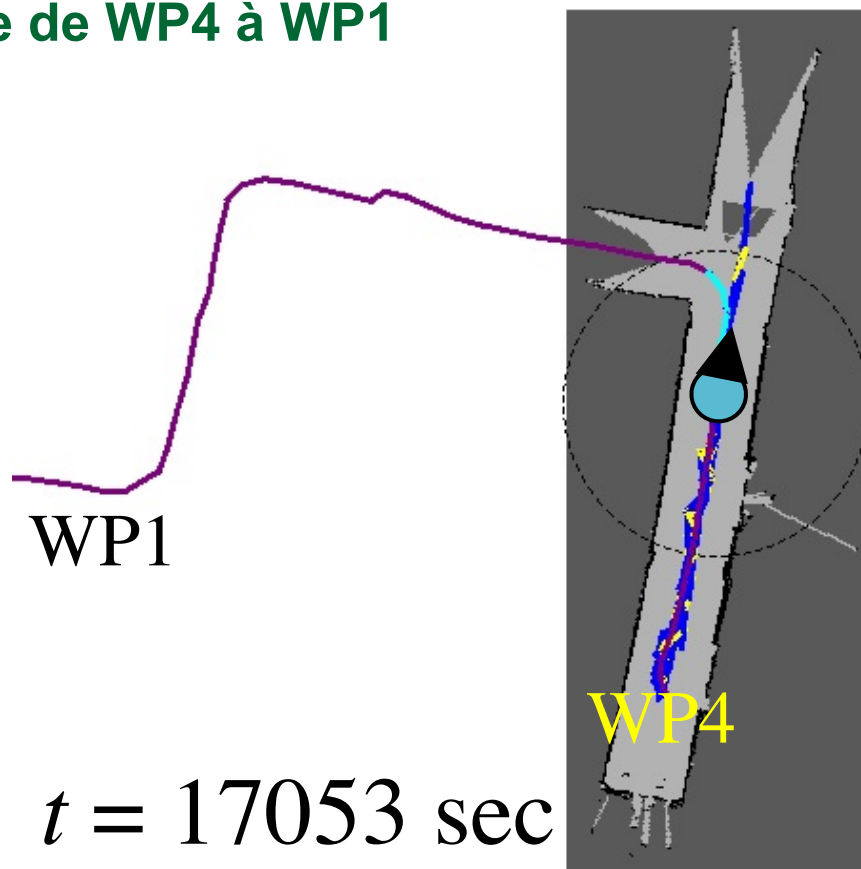
Suivi de trajectoire de WP4 à WP1

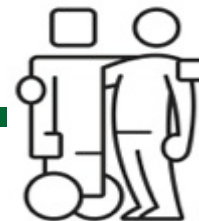




## Gestion de mémoire

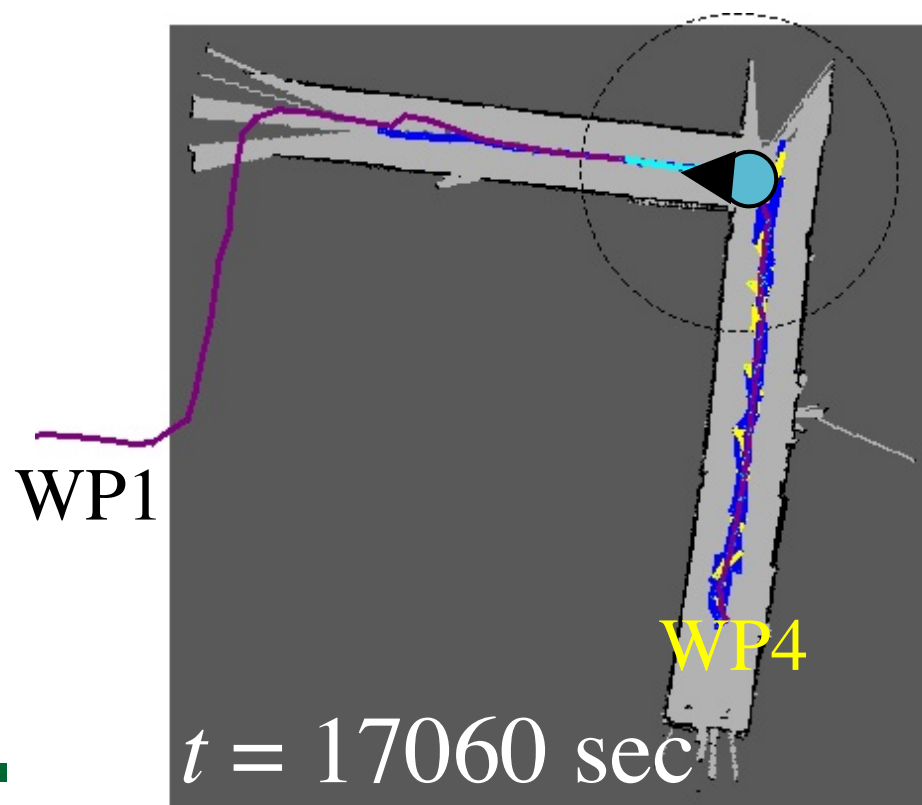
### Suivi de trajectoire de WP4 à WP1

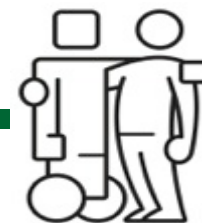




## Gestion de mémoire

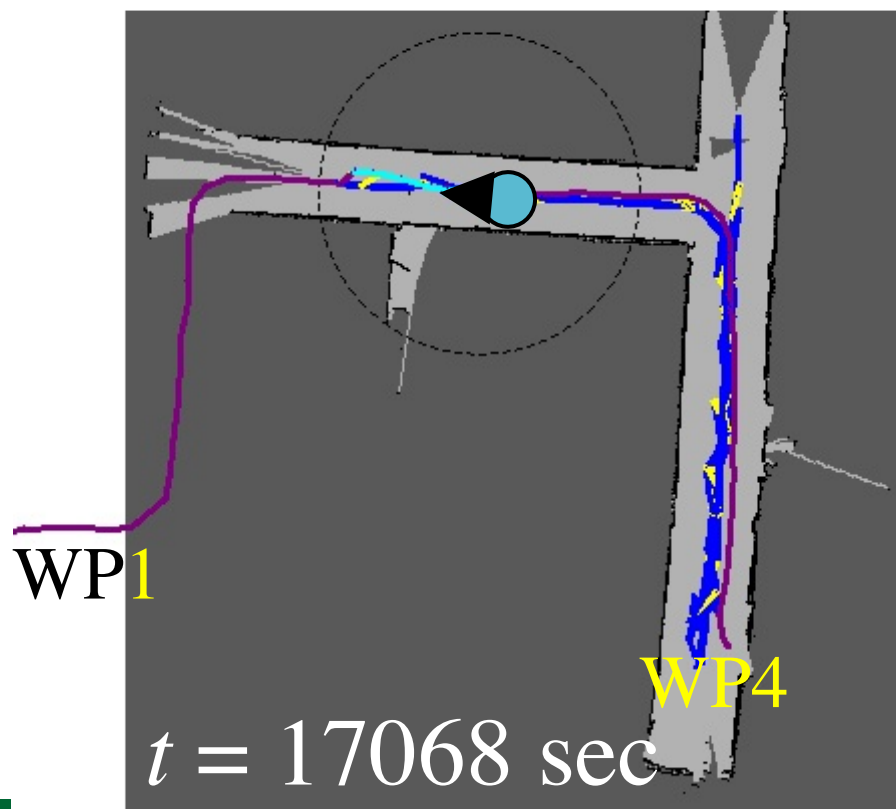
### Suivi de trajectoire de WP4 à WP1





## Gestion de mémoire

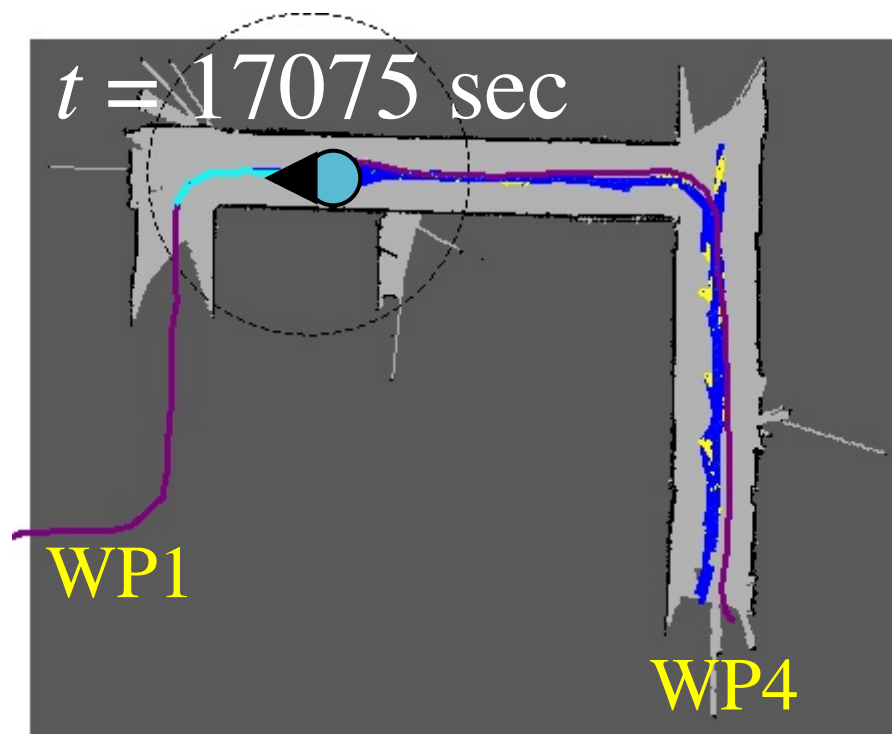
### Suivi de trajectoire de WP4 à WP1





## Gestion de mémoire

### Suivi de trajectoire de WP4 à WP1

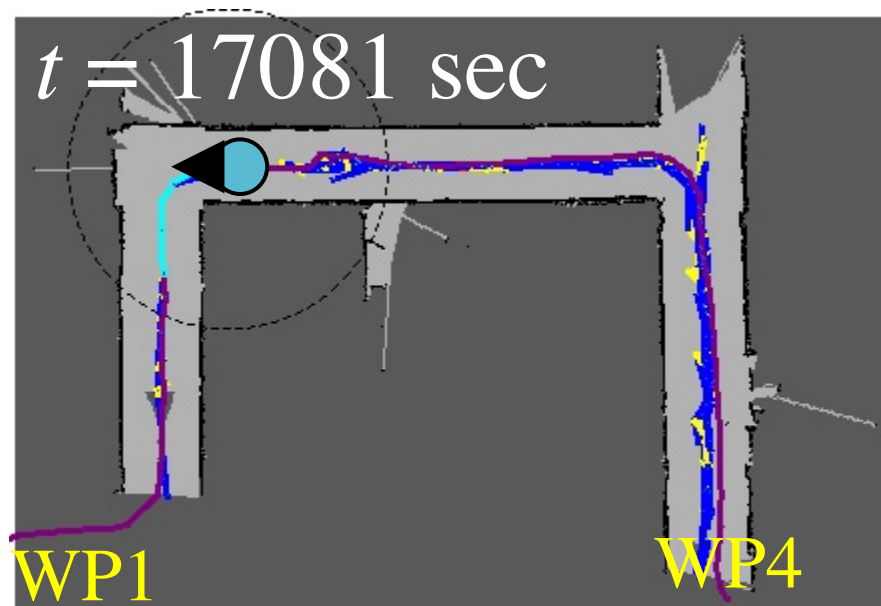






## Gestion de mémoire

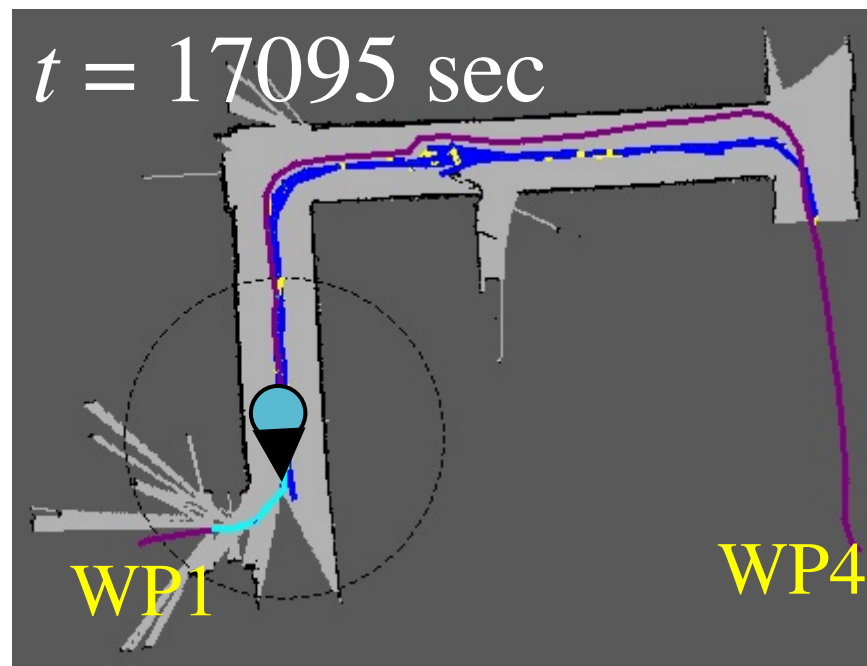
### Suivi de trajectoire de WP4 à WP1





## Gestion de mémoire

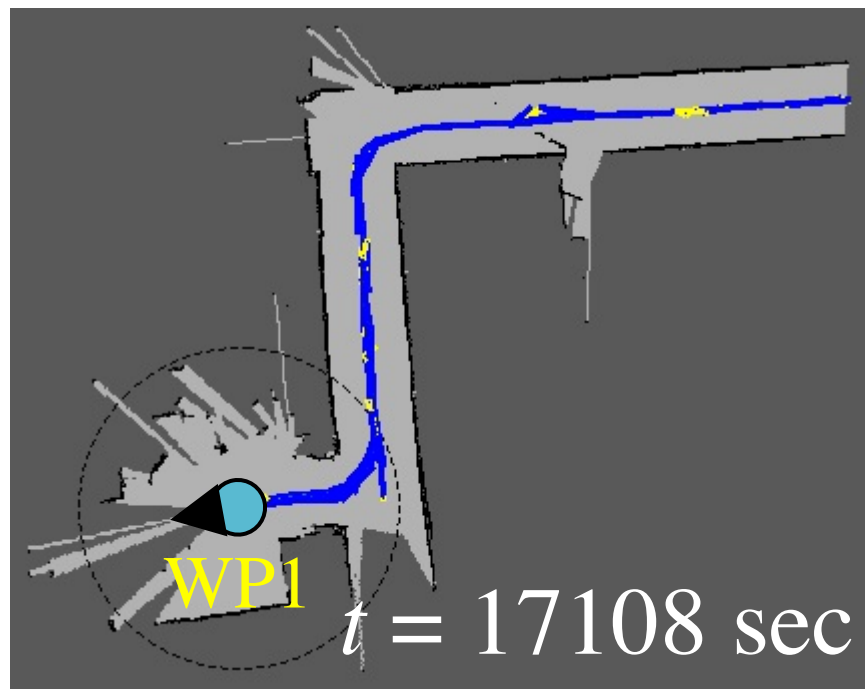
### Suivi de trajectoire de WP4 à WP1





## Gestion de mémoire

### Suivi de trajectoire de WP4 à WP1

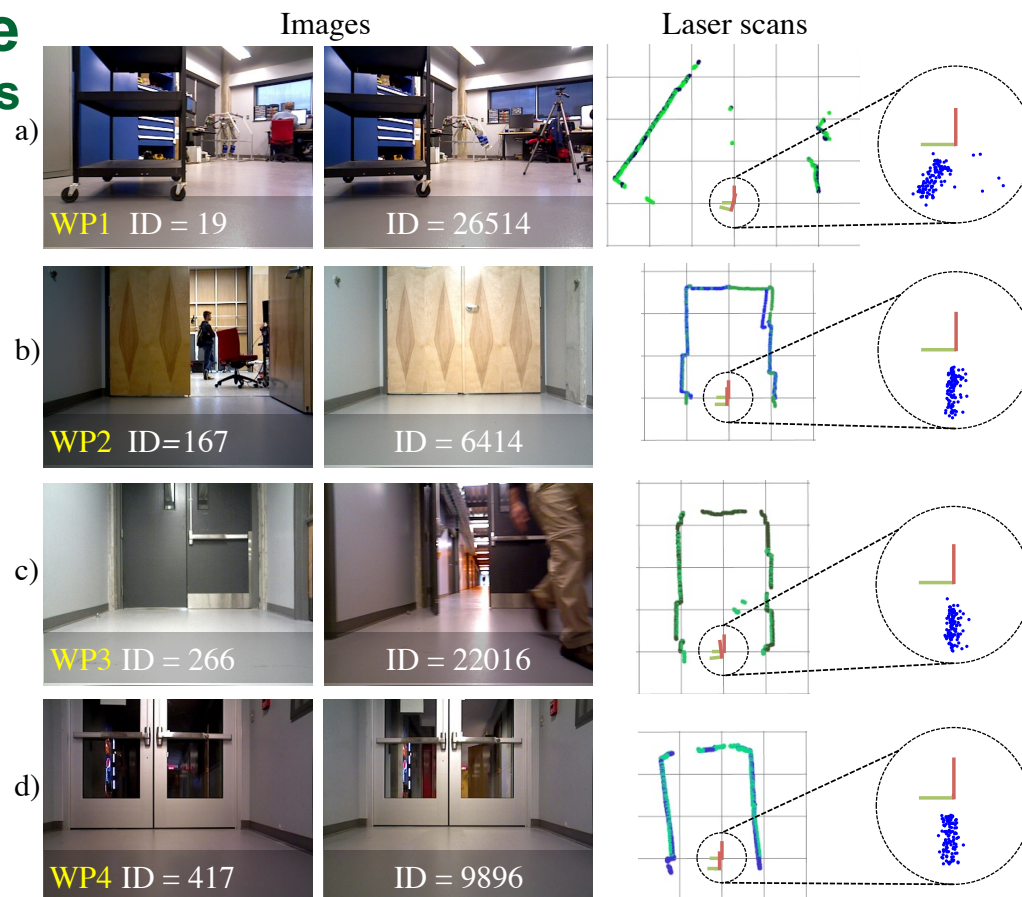


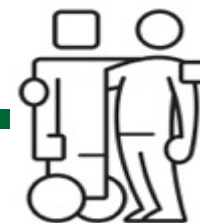


## Gestion de mémoire

### Performance d'atteinte des buts

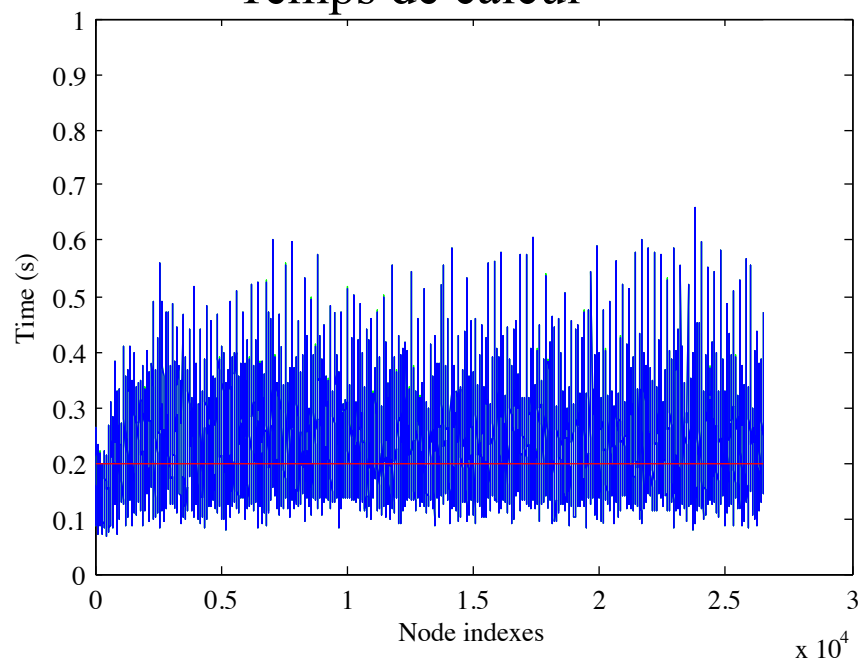
445 fois sur 446



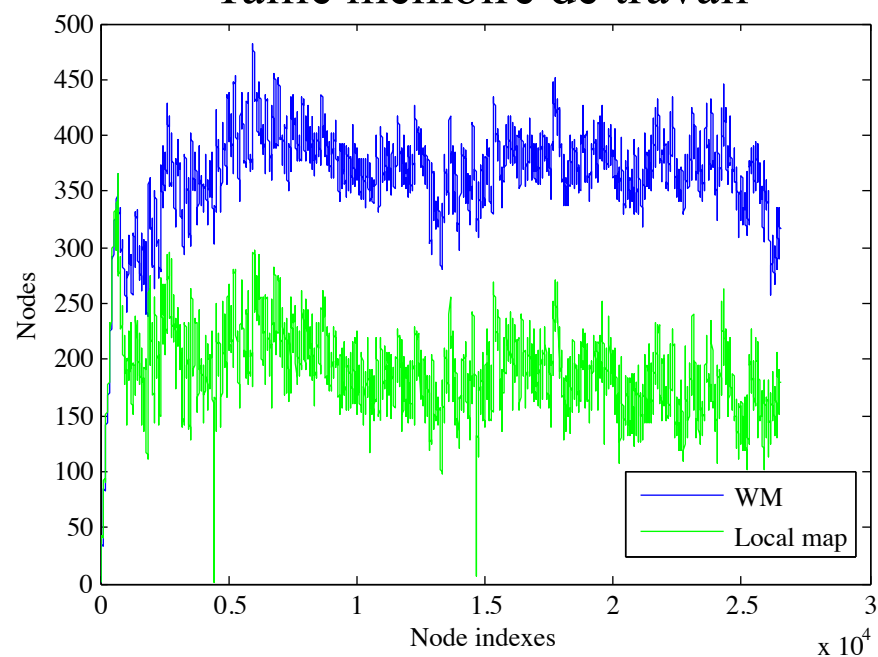


## Gestion de mémoire

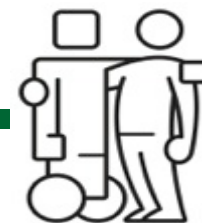
Temps de calcul



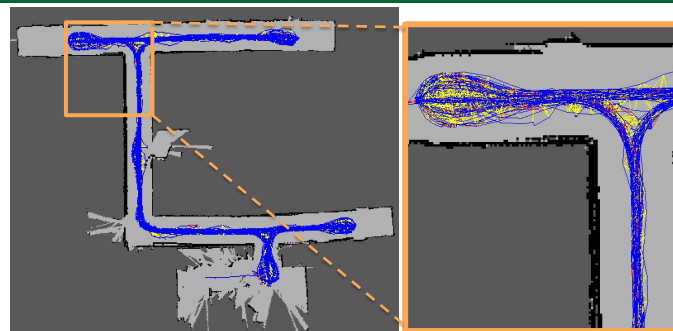
Taille mémoire de travail



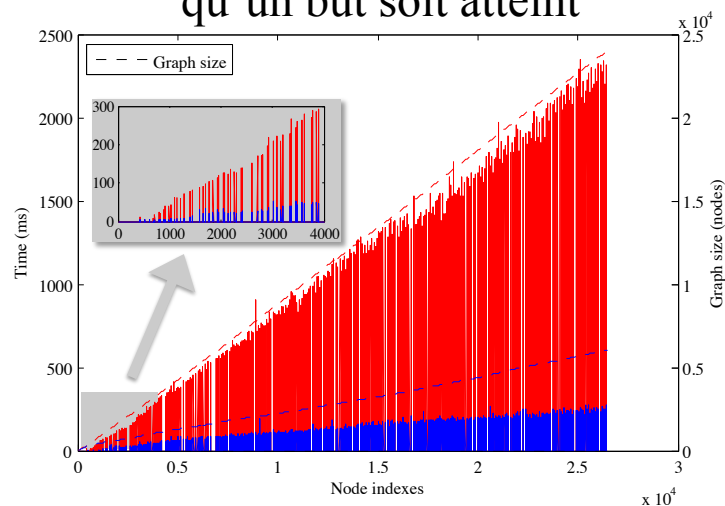
## Gestion de mémoire Variables non constantes



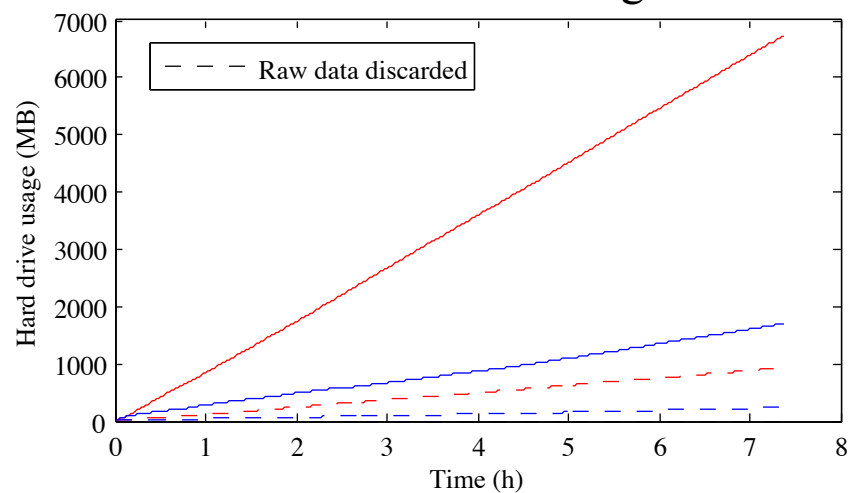
24002 noeuds  
113368 liens

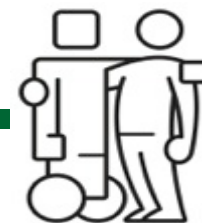


Temps de planification après  
qu'un but soit atteint



Taille de la mémoire à long terme

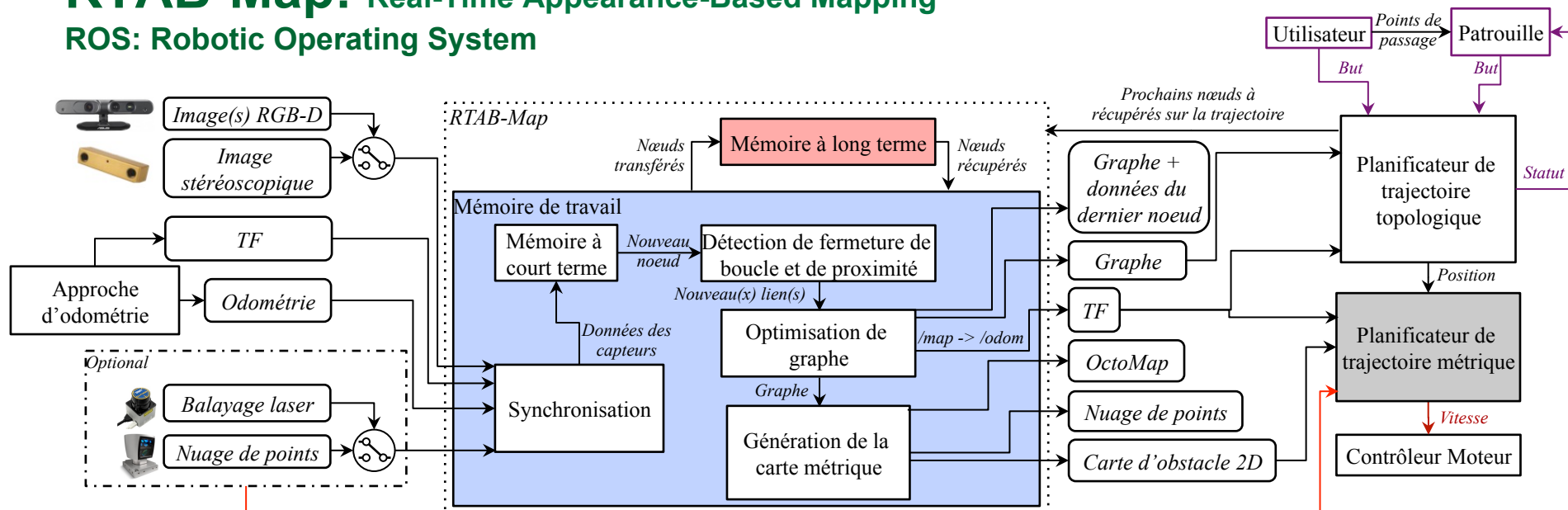


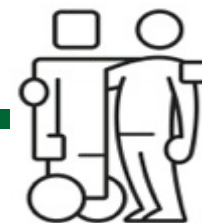


# Architecture du système

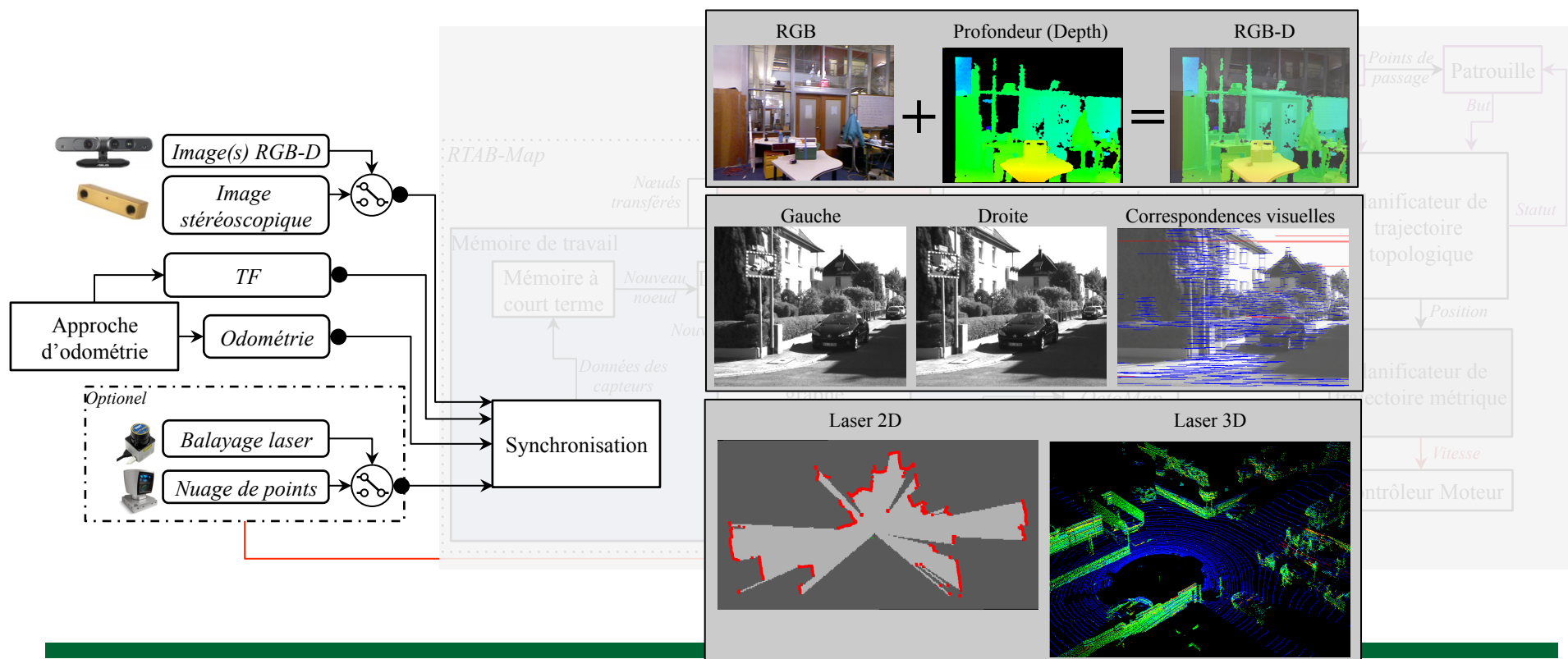
## RTAB-Map: Real-Time Appearance-Based Mapping

### ROS: Robotic Operating System

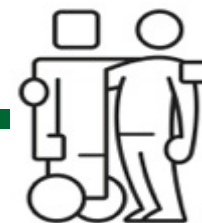




# Architecture du système

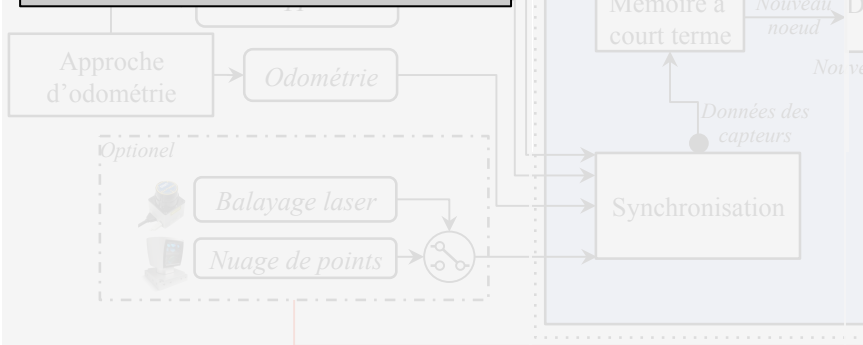
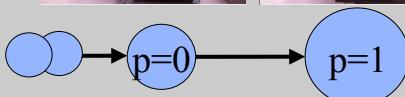




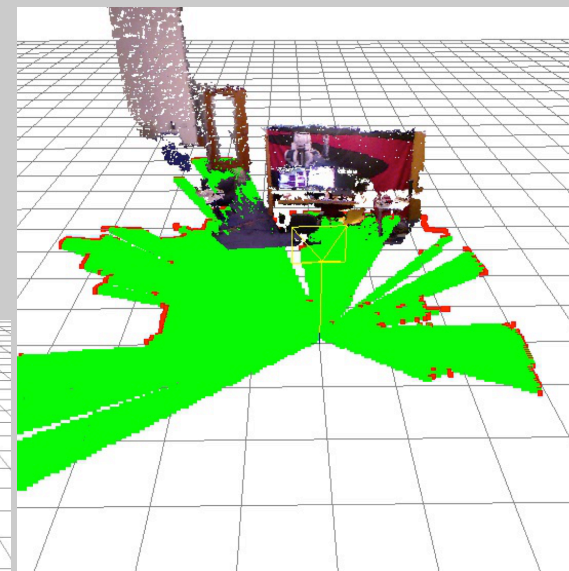
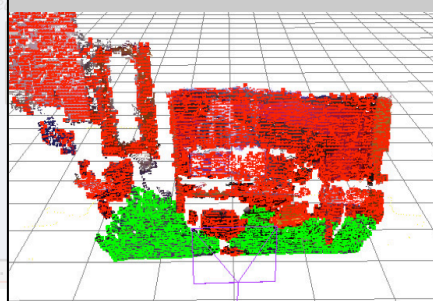


# Architecture du système

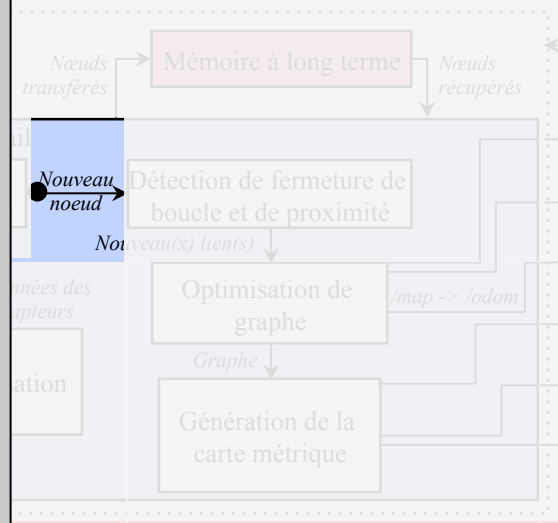
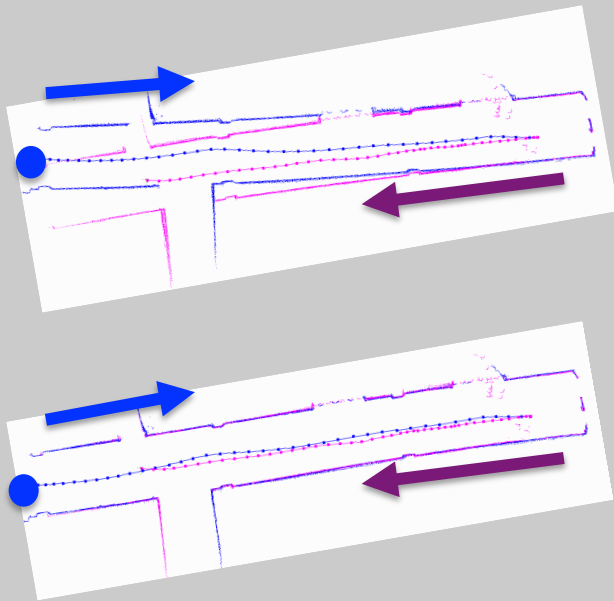
## Mise à jour des poids



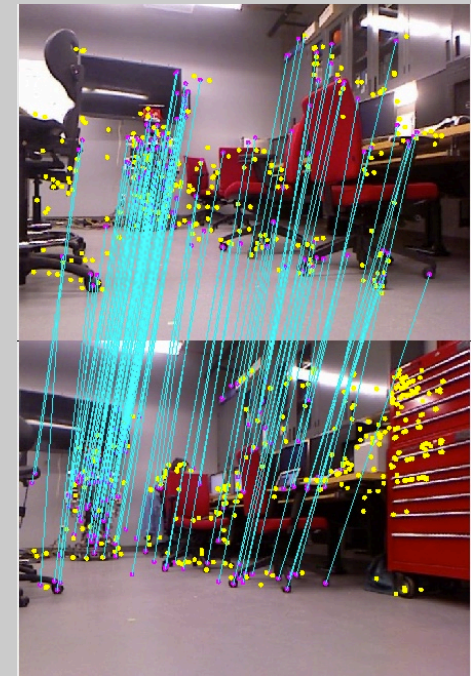
## Création de la carte locale du noeud

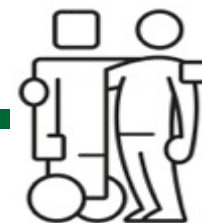


## Détection de proximité avec laser



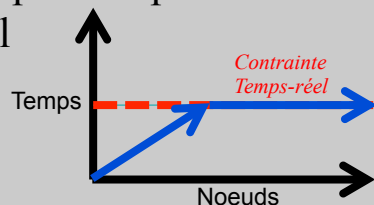
## Détection de boucle visuelle



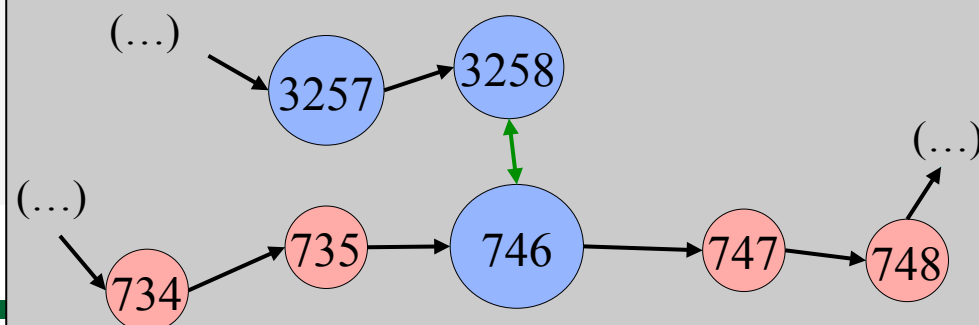


# Architecture du système

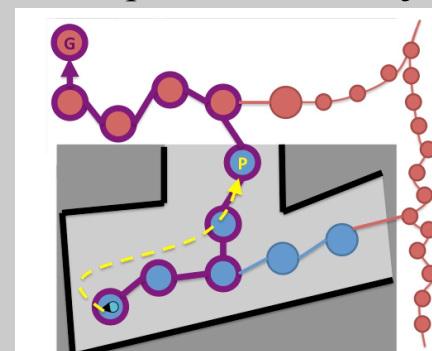
Transfert pour respect de la contrainte temp-réel

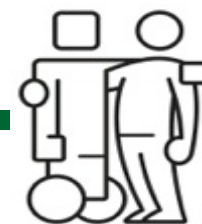


Récupération pour détection de fermeture de boucle



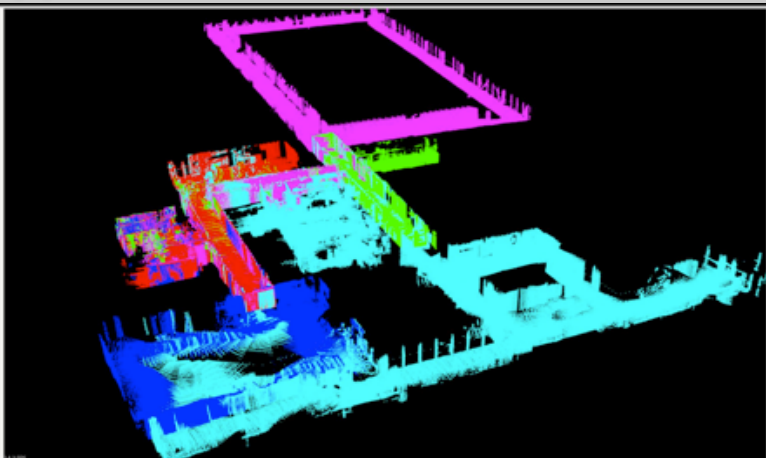
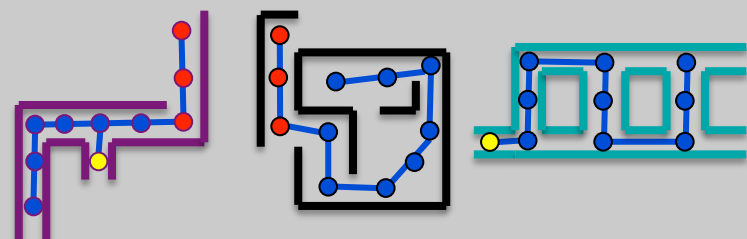
Récupération pour suivi de trajectoire



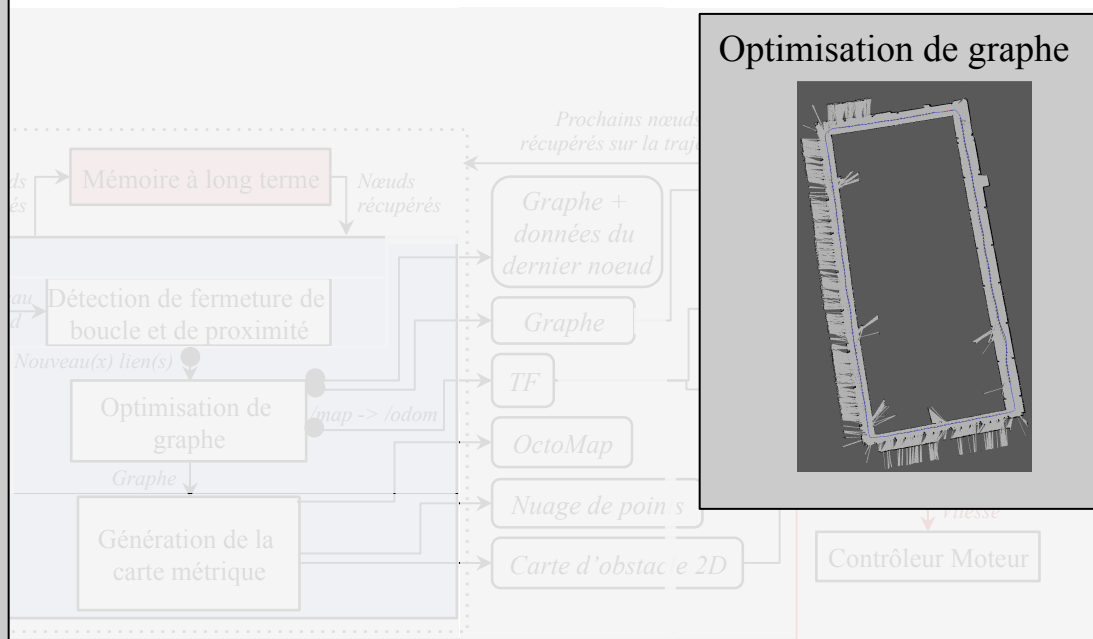
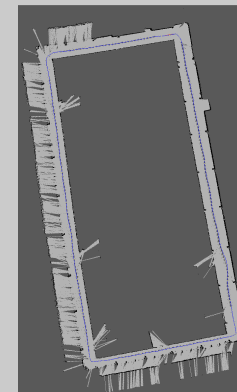


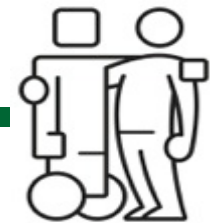
# Architecture du système

Fusion de graphes (multi-session)

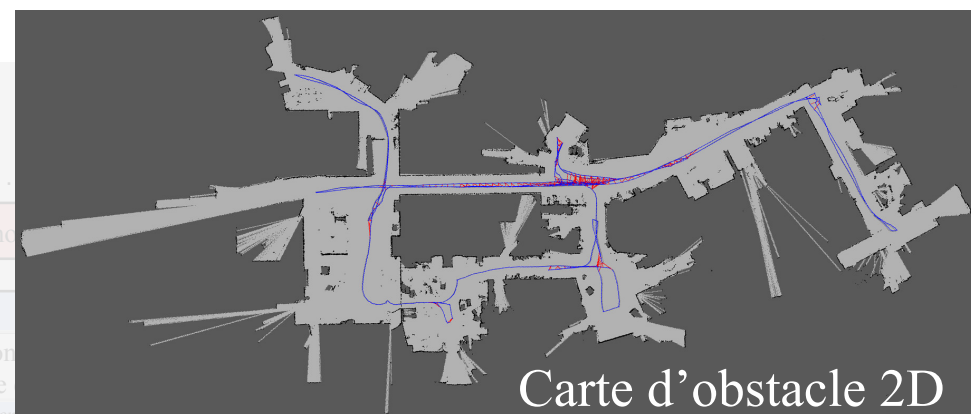
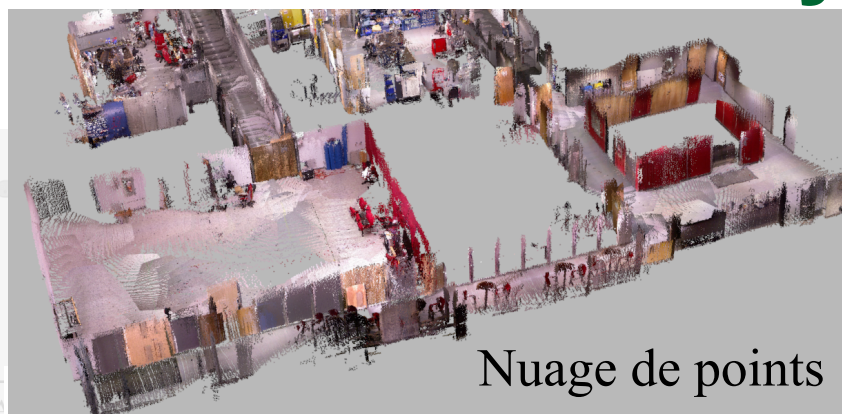


Optimisation de graphe

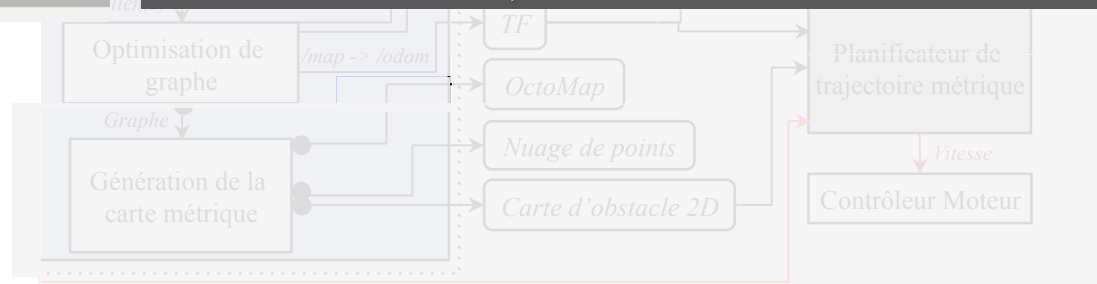
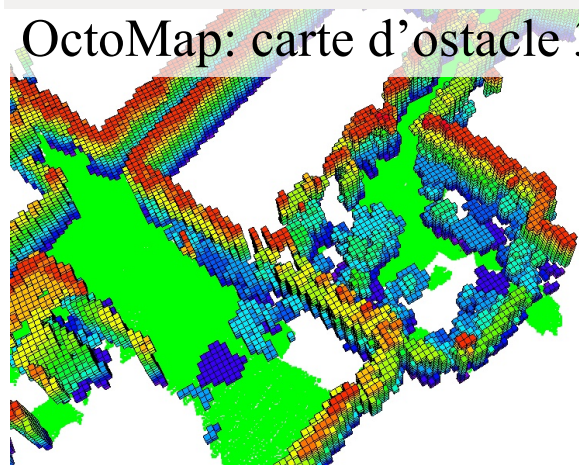




# Architecture du système

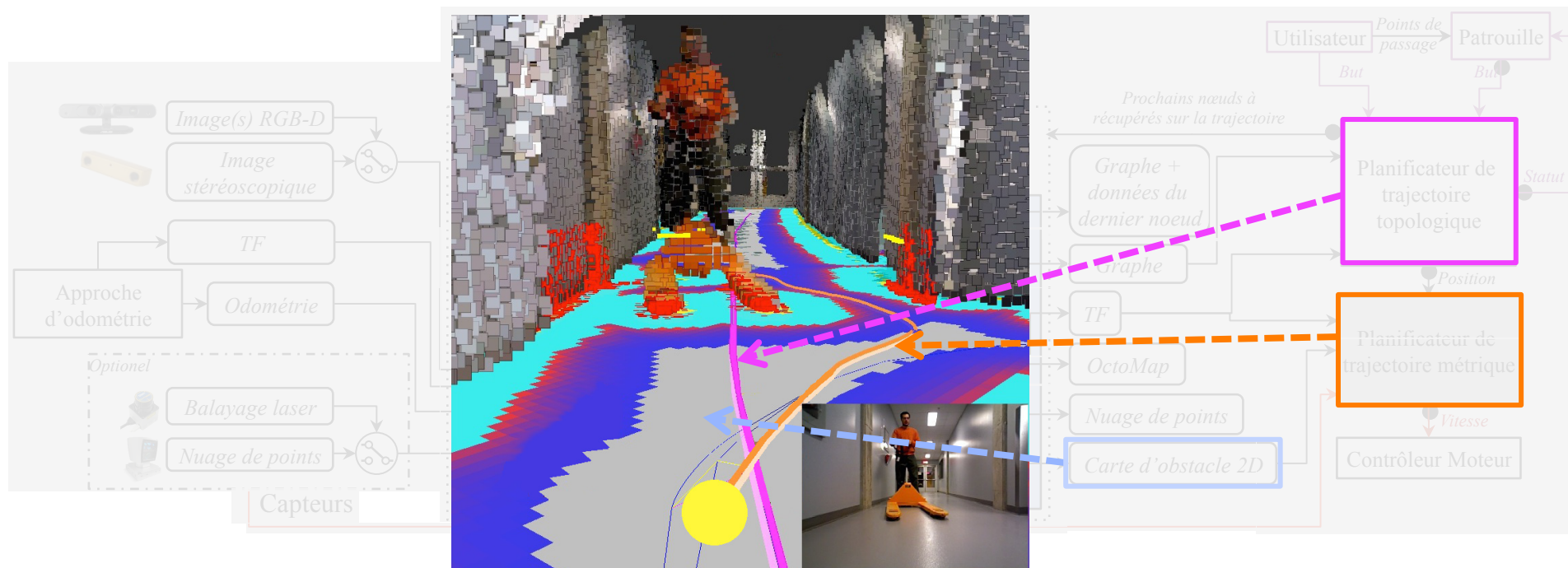
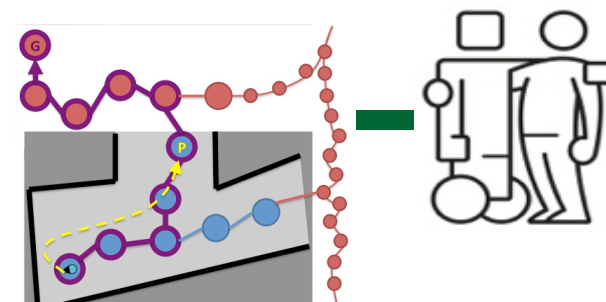


OctoMap: carte d'obstacle 3D





# Architecture du système

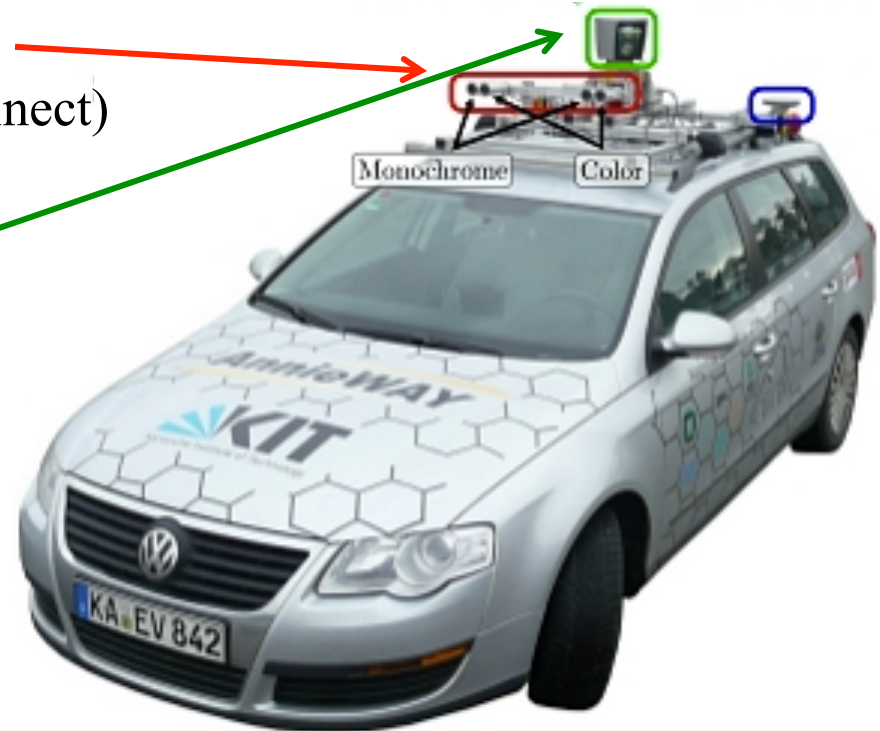
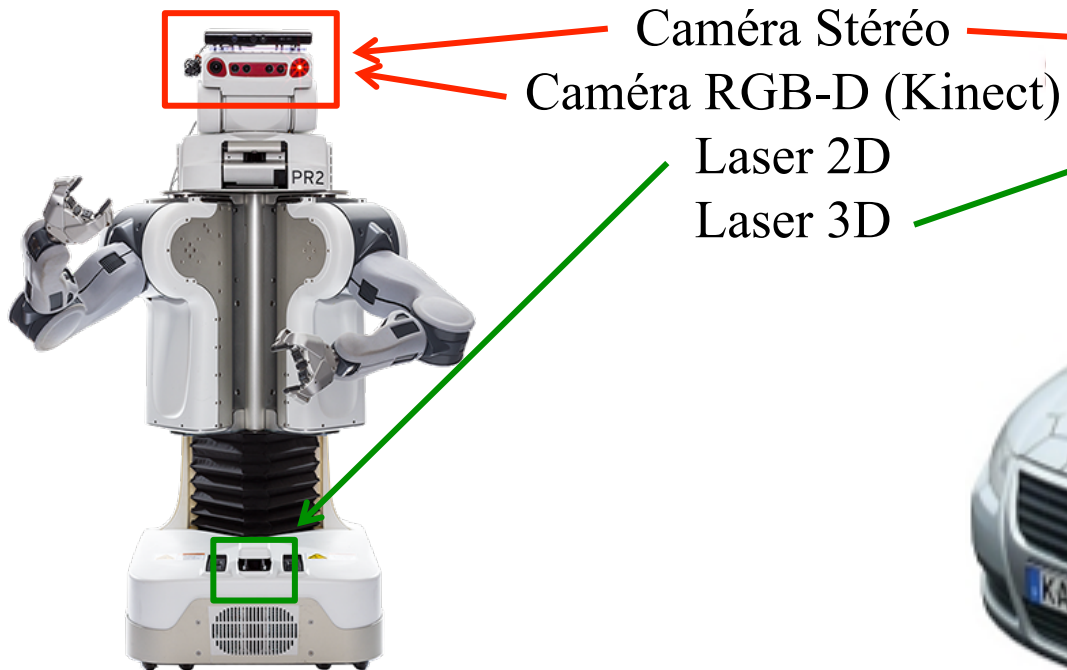




## Comparaison SLAM visuel vs géométrique

MIT Stata Center

KITTI

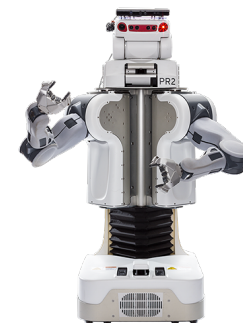
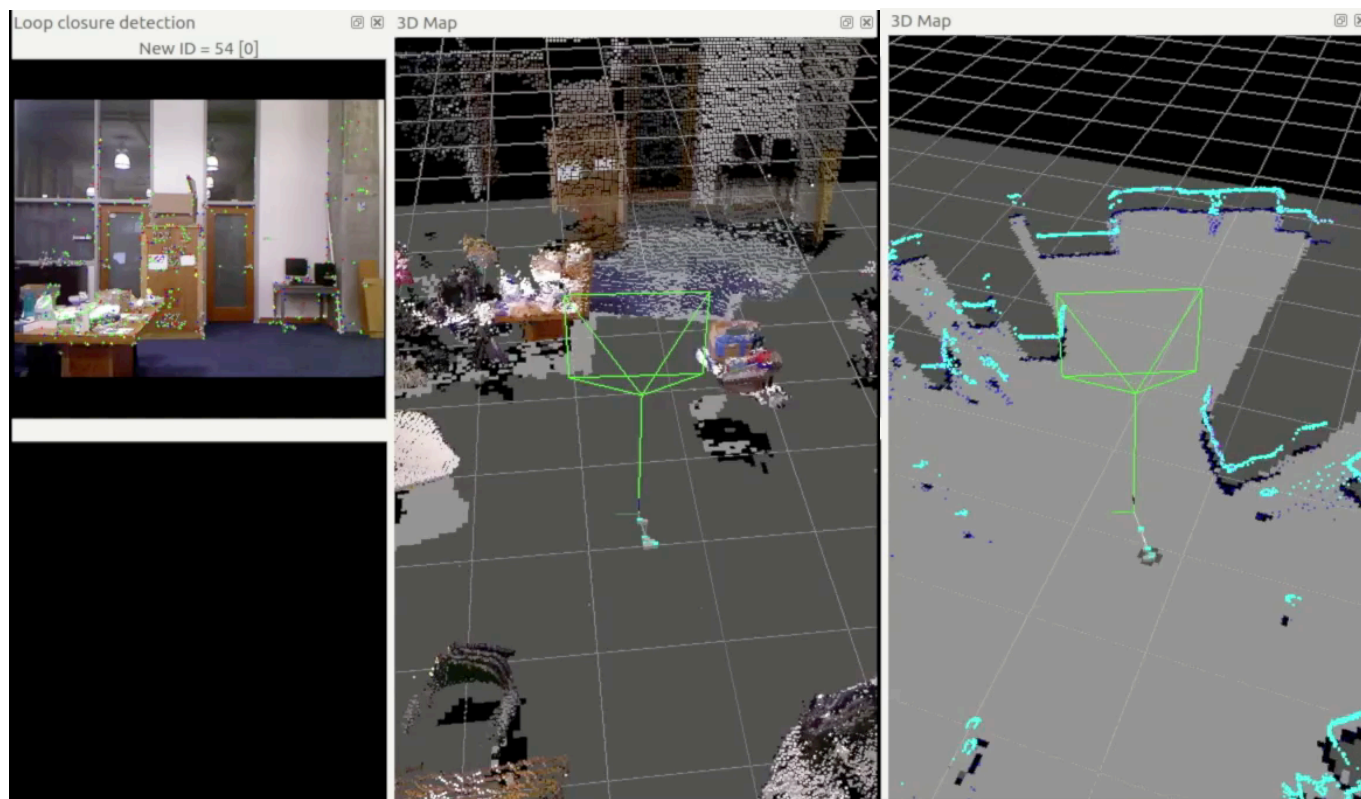


Robot PR2



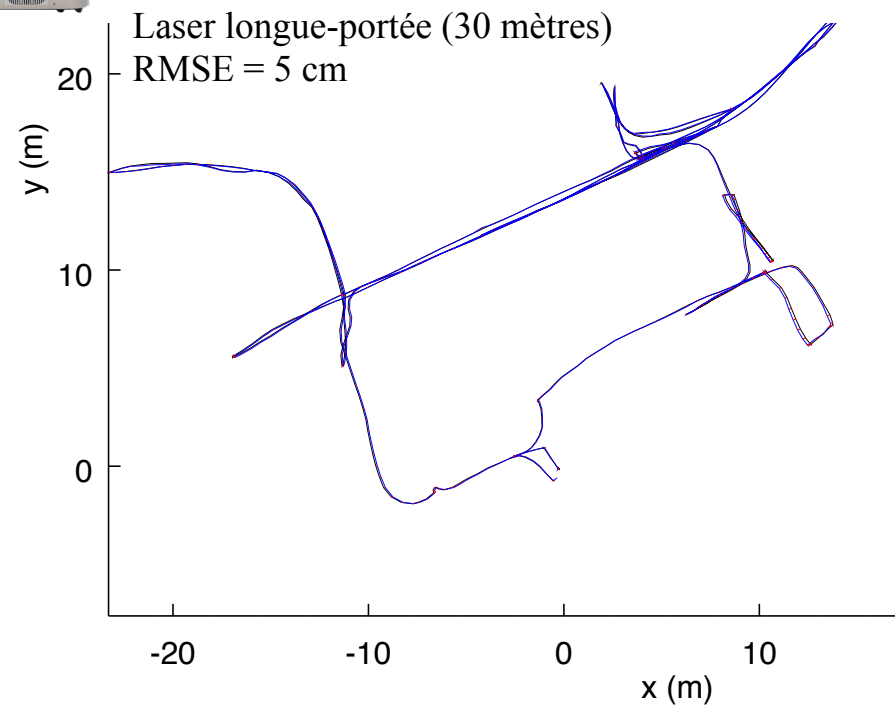
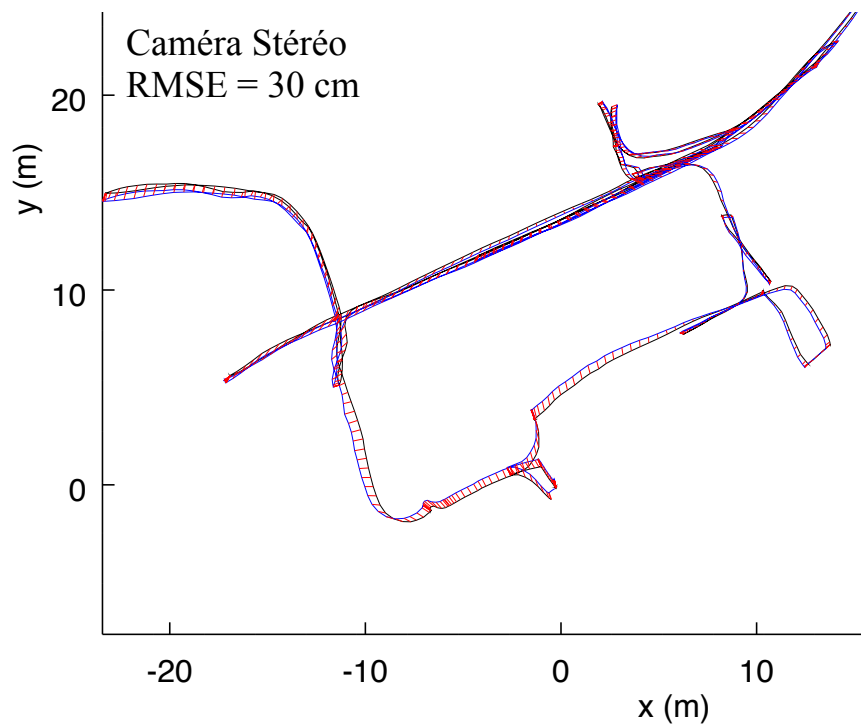
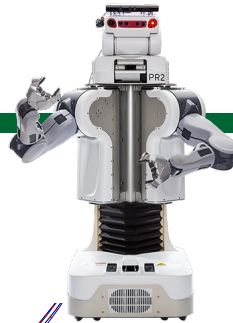
Caméra RGB-D

Laser 2D

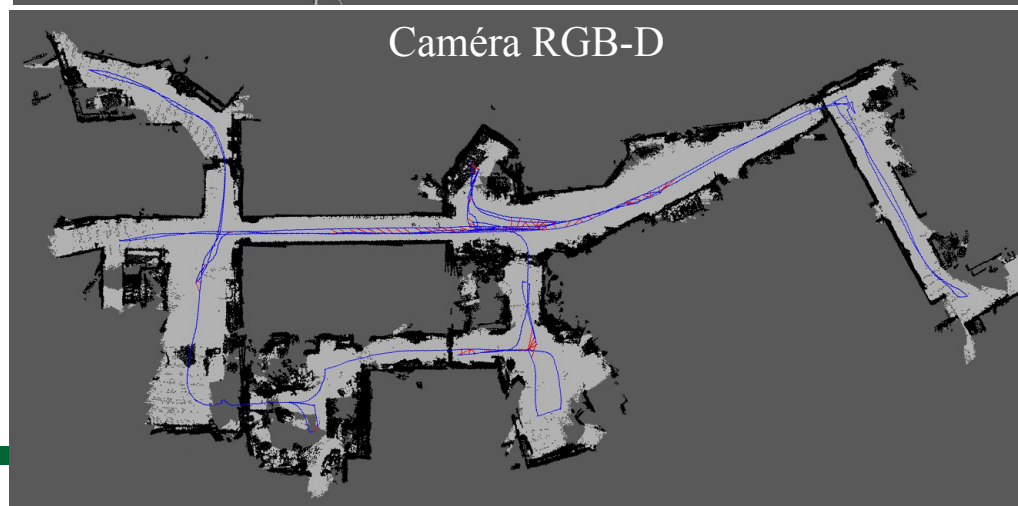
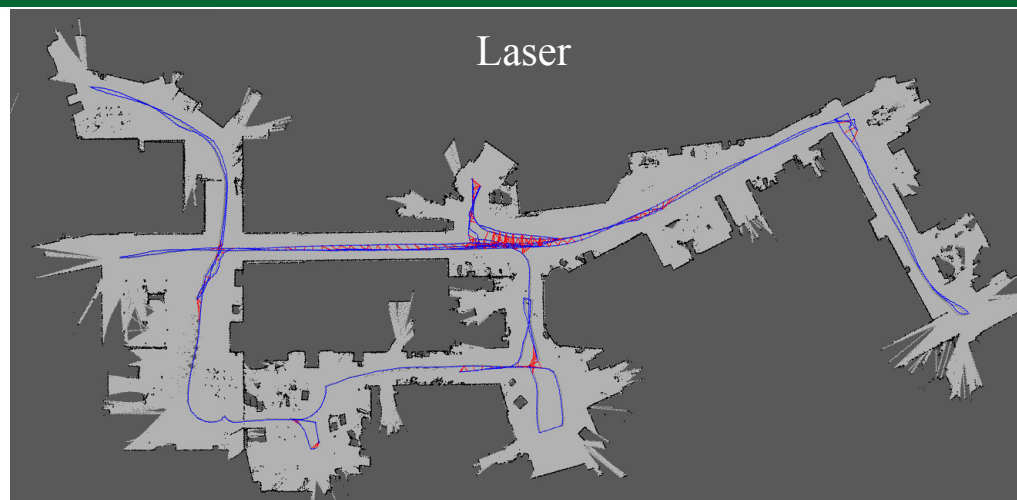
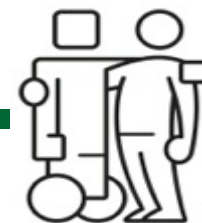


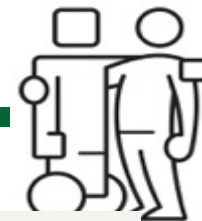
*Séquence 2012-01-25-12-14-25*





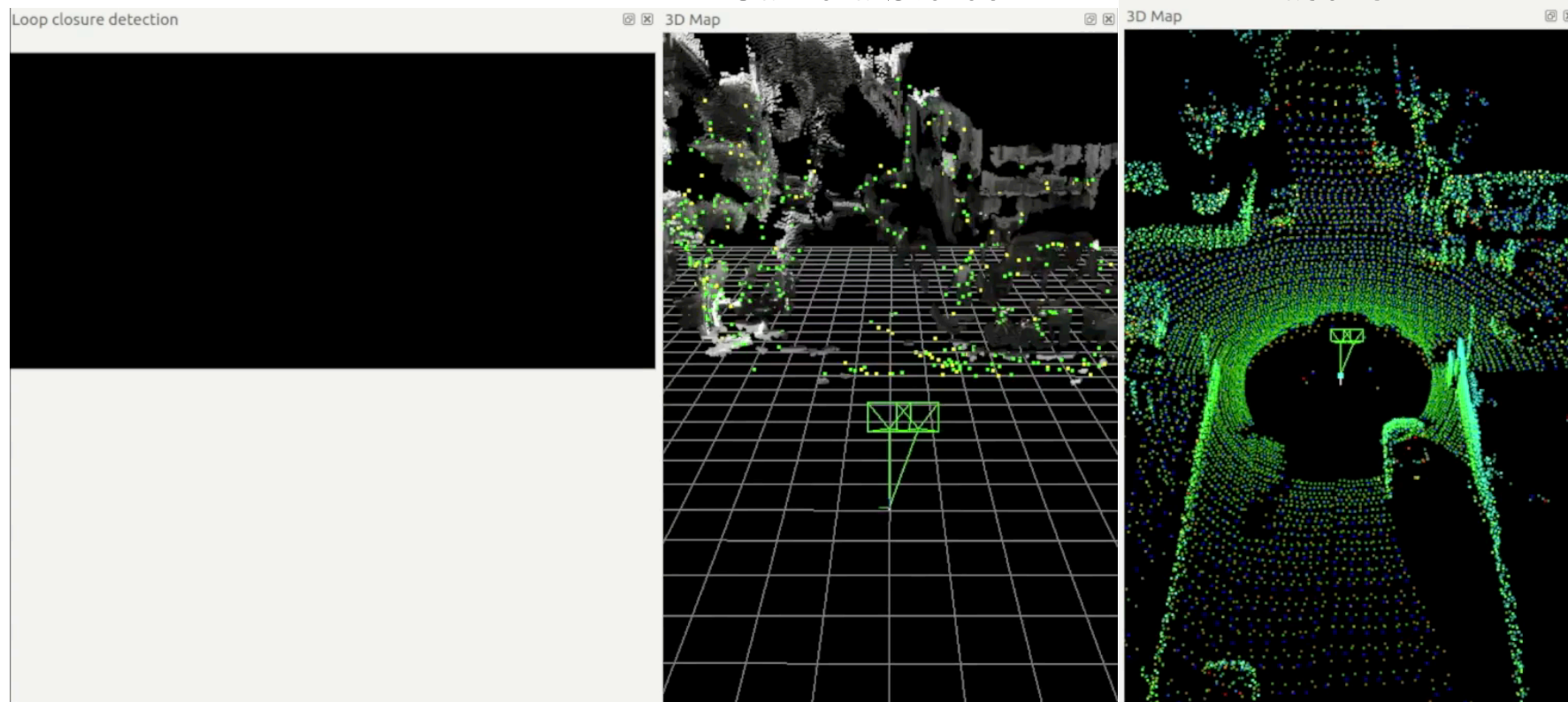
*Séquence 2012-01-25-12-14-25*





Caméra Stéréo

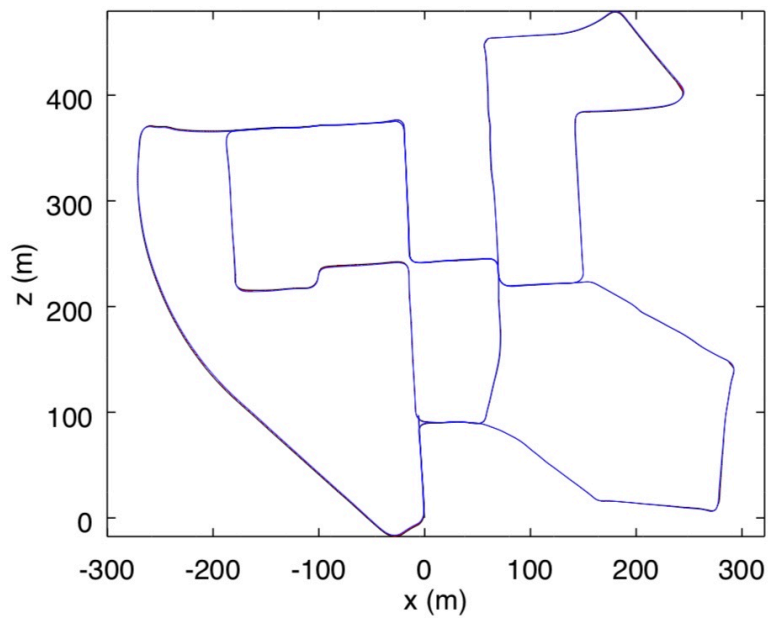
Laser 3D



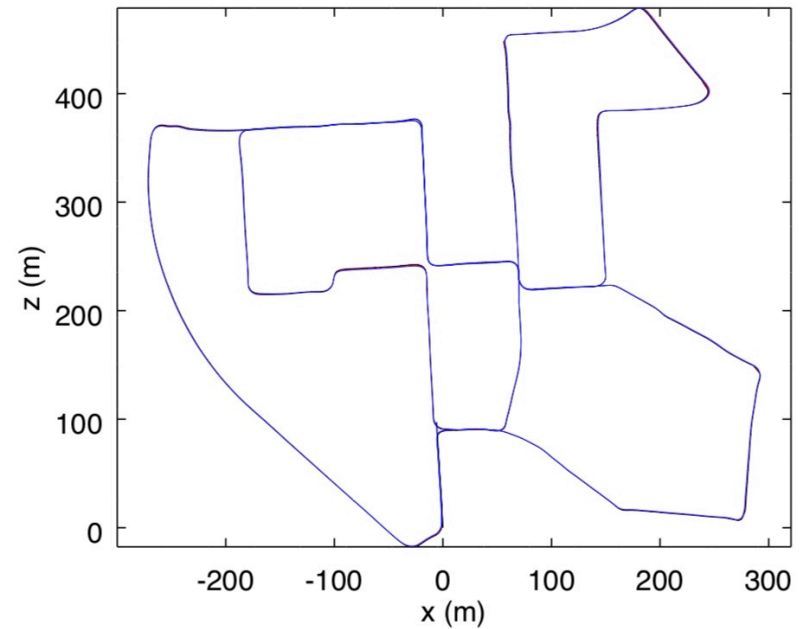
*Séquence 07*



Caméra stéréo:  
RMSE = 1 m

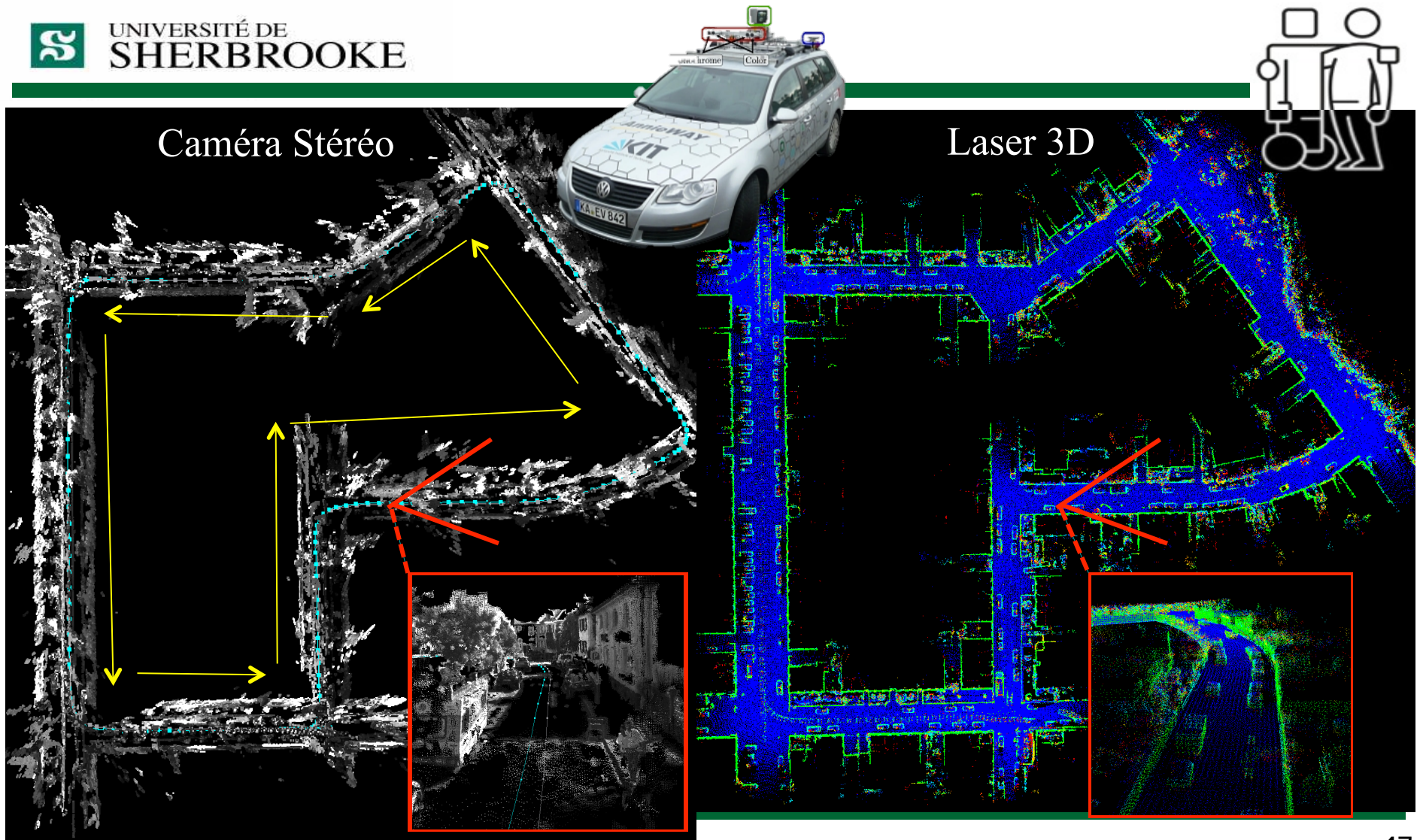
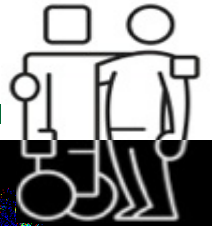


Laser 3D:  
RMSE = 1 m



*Séquence 00*





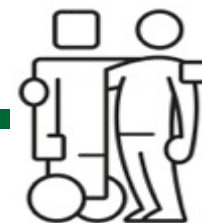
*Séquence 07*



# En résumé

Approches de SLAM disponibles pour robots mobiles (compatibles ROS)

		Inputs							Online Outputs				Gestion de mémoire*
		Stereo	Camera			Lidar		Odom	Pose	Occupancy		Point Cloud	
			RGB-D	Multi	IMU	2D	3D			2D	3D		
Laser	GMapping					✓		✓	✓	✓			
	TinySLAM					✓		✓	✓	✓			
	Hector SLAM					✓			✓	✓			
	ETHZASL-ICP					✓	✓	✓	✓	✓		Dense	
	Karto SLAM					✓		✓	✓	✓			
	Lago SLAM					✓		✓	✓	✓			
	Cartographer					✓	✓	✓	✓	✓		Dense	
	BLAM						✓		✓			Dense	
	SegMatch						✓					Dense	
Caméra	VINS-Mono				✓				✓				
	ORB-SLAM2	✓	✓										
	S-PTAM	✓							✓			Sparse	
	DVO-SLAM		✓						✓				
	RGBiD-SLAM		✓										
	MCPTAM	✓		✓					✓			Sparse	
	RGBDSLAMv2		✓					✓	✓		✓	Dense	
	RTAB-Map	✓	✓	✓		✓	✓	✓	✓	✓	✓	Dense	✓



# Conclusion

Exemples de projets utilisant RTAB-Map:

- Fauteuil roulant autonome peu coûteux
- MANUELA (Orano): Instrumentation de mesure nucléaire
- MapIt: une application mobile pour la représentation virtuelle 3D de l'environnement domiciliaire au service du handicap et de la rééducation

